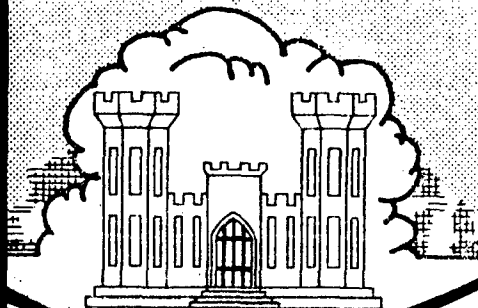


DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA



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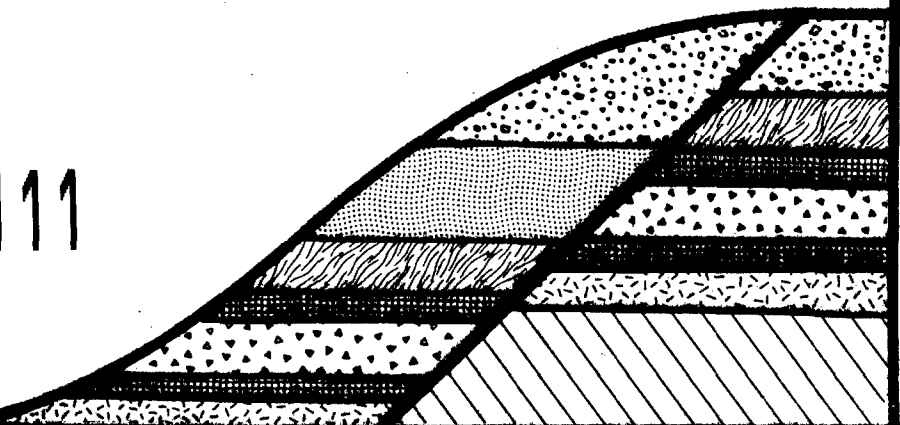
FAULT EVALUATION STUDY

MARYSVILLE LAKE PROJECT
PARKS BAR ALTERNATE
YUBA RIVER, CALIFORNIA

BUTTE, YUBA, NEVADA AND PLACER COUNTIES, CALIFORNIA

MAY 1977

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MARYSVILLE LAKE PROJECT FAULT EVALUATION STUDY
SACRAMENTO DISTRICT, US ARMY CORPS OF ENGINEERS

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MARYSVILLE LAKE PROJECT FAULT EVALUATION STUDY
SACRAMENTO DISTRICT, US ARMY CORPS OF ENGINEERS

1. Introduction. - The occurrence of the 1 August 1975 earthquake with its epicenter just south of Oroville (Richter magnitude 5.7) changed the general assessment of seismic risk in the northern Sierra Nevada foothill area and generated several studies by state and federal agencies. Prior to the Oroville earthquake, geologists and seismologists generally felt that significant earthquakes that might affect the western Sierra Nevada foothill area would originate from distant sources. Historically, moderate to strong earthquakes have originated from sources to the east or west except for one in the northern part of the Sierra Nevada foothills. There are no other historical data or other evidence to suggest that fault structures known to be present were capable of generating significant seismic activity. The Foothills Fault System and a probable associated regional shear zone that passes through the project area were considered to be long-dead structures with the exception of the northern end which presumably had generated the one nearby moderate earthquake. Surface ruptures associated with the 1975 earthquake and subsequent after-shocks are in alignment with a prominent linear topographic trend, the Swain Ravine lineament, that projects southeastward through the Dry Creek-Parks Bar area. This suggests the possibility that seismic activity could migrate southward from the Oroville area and have a greater effect on the Marysville project than had previously been thought possible.

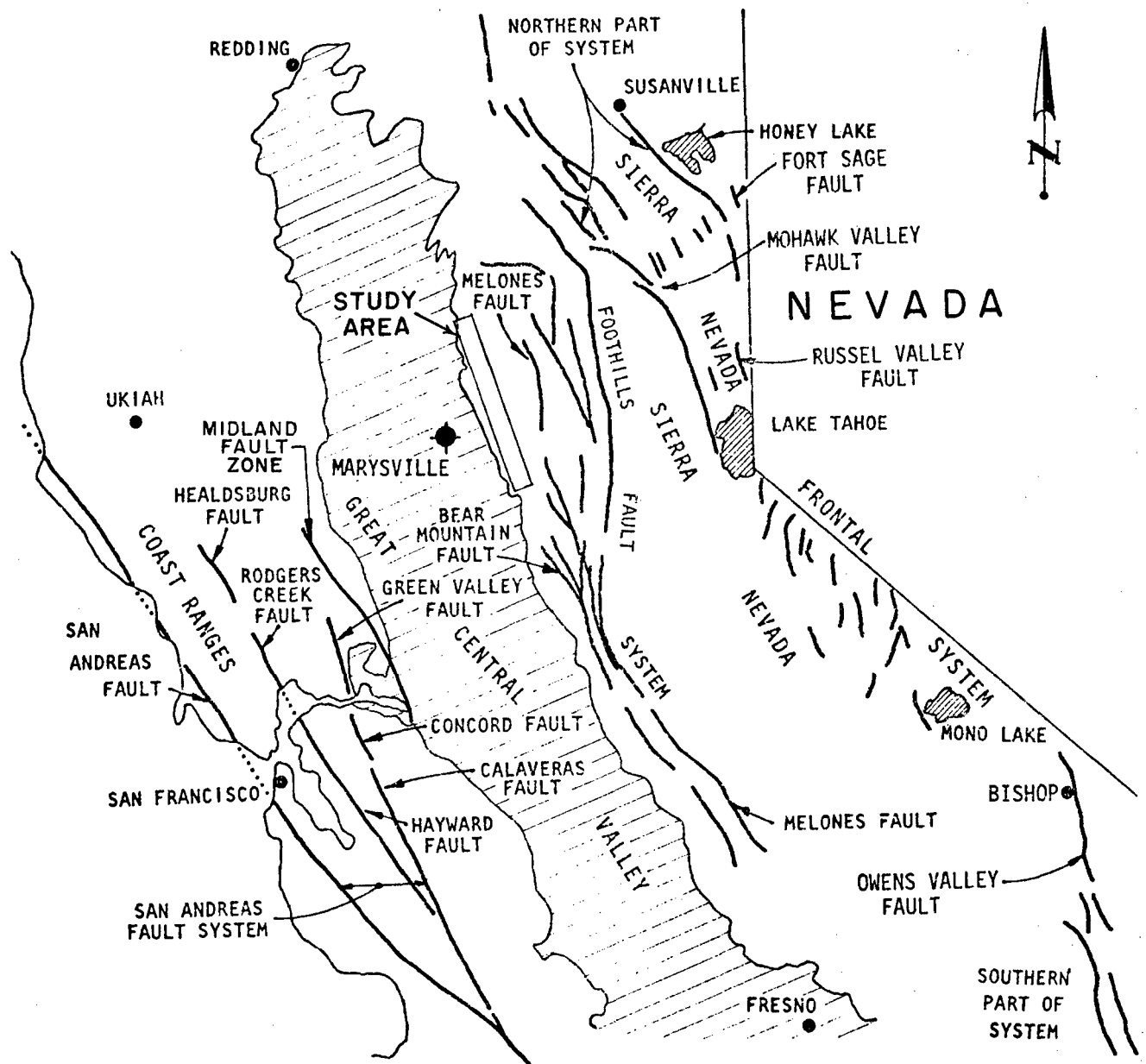
2. Location of the study. - The overall study covered approximately a 3 to 10 mile wide by 45 mile long area along the western Sierra Nevada foothills between Lincoln and Oroville (General Location and Fault Map). The study was concentrated in the present Marysville project area which includes the Afterbay, Dry Creek, and Yuba River (at Parks Bar) Damsites located about 13 to 17 miles east of Marysville. The project area is shown on geologic map, Plate III.

3. The purpose of the study was threefold: (a) To determine if there had been any surface cracking or faulting within the project area related to the Oroville earthquake sequence, (b) to investigate structures associated with the Swain Ravine and other lineaments and to determine the relationship between them and the 1975 faulting that occurred on the Cleveland Hill fault, and (c) to determine if there has been recent seismic activity within the project area. The study included a comprehensive review of geological reports and maps of the region, the use of data from interpretation of vertical and low-sun-angle aerial photographs, sidelooking airborne radar (SLAR) and Earth Resources Technology Satellite (ERTS) imagery, the compilation of data collected by other agencies investigating the Oroville earthquake and regional tectonics, reconnaissance geological field mapping throughout the regional shear zone, detailed mapping in the project area and subsurface exploration of the Swain Ravine lineament by trenching.

4. Regional geology. - The project area is located in the northern part of the Western Sierra Nevada Metamorphic Belt. The entire belt, approximately 20-40 miles wide and 180 miles long, consists of a series of northwest trending assemblages of metamorphosed Paleozoic and Mesozoic volcanic and sedimentary rocks which have been intruded by Mesozoic igneous bodies. Locally, this basement complex is unconformably overlain by erosional remnants of a formerly extensive capping of Tertiary volcanic rocks and Tertiary and Quaternary sedimentary deposits. Similar rock types occur throughout the study area, which is shown on the General Location and Fault Map and Plates I to V.

The foothills area is structurally complex and has been subjected to varying degrees of folding, shearing, and faulting, most of which apparently occurred at the close of the Jurassic Period (Clark, 1964, 1976). The dominant structural feature of the area is a wide regional shear zone which may be a northern extension of the Bear Mountain Fault Zone. The more recent geologic and fault maps do not show the shear zone boundaries and have replaced the entire zone with a single, long fault line (Jennings, 1973; Clark, 1976) approximating the location of the Prairie Creek lineament which is described in Section 7, Areal geology. The relationship between the shear zone and the Bear Mountain Fault Zone is not well understood, but the two features appear to be different in nature. On the Geologic Map of California (Burnet and Jennings, 1962; Strand and Koenig, 1965) the two zones are separated by the Rocklin Pluton, which is a large body of intrusive igneous rock of Cretaceous age. The faults of the Western Metamorphic Belt have been variously interpreted within the concept of global plate tectonics as representing sutures or plate boundaries formed during plate convergence and subduction during Jurassic time, or that the regional shear zone represents a melange separating relatively undeformed volcanics to the west from pillow basalt, dike complex, and intrusive rock of the Smartville ophiolite sequence to the east (Cady, Moores, and Schweickert and Cowan, 1975 - in Woodward-Clyde Consultants, April 1976). Duffield and Sharp (1975) have re-interpreted similar rocks to the south, in Amador County, as being part of a melange with a limited degree of internal order representing a subduction zone in which subhorizontal faulting occurred at a continental margin before the strata were tilted to their present steeply dipping position during the Nevadan orogeny. The melange may mark the locus of convergence between an oceanic plate that abuts and plunges beneath a continental margin.

5. Regional tectonics. - Historically, active faults with large earthquake motions significant to the project area have been related to the San Andreas Fault System to the west, the Midland Fault Zone on the west side of the Great Valley, the Sierra Nevada Frontal Fault System to the east or possibly from one of the many faults in the Basin and Range Province of Nevada (Woodward-Lundgren & Associates, 1975). The major fault systems are shown on the General Location and Fault Map.



NOTE:

Map modified from a report prepared by Woodward - Clyde Consultants, April 1976.

MAP 1
GENERAL LOCATION AND FAULT MAP

Prior to the Oroville earthquake, there was no evidence to suggest that the regional shear zone or any of the faults in the Foothills Fault System was a source of significant earthquakes or surface faulting (Woodward-Clyde Consultants, April 1976). The major structure of the Western Sierra Nevada Metamorphic Belt is the Foothills Fault System (Clark 1960, 1964) which consists of two main components, the Melones Fault Zone to the east and the Bear Mountain Fault Zone to the west. The regional shear zone in the project area is on the same northwest trend as the Bear Mountain Fault Zone south of the Cosumnes River.

6. Seismicity. - The epicenter for the Oroville earthquake on 1 August 1975 was located about 5-1/2 miles south of Oroville and just east of Palermo. Its location is at the center of the line between Sections 4 and 9, T. 18N., R. 4E., on the USGS Palermo, California 7-1/2 minute quadrangle map, 1970 (Plate IV). The epicenter was about 17 miles northwest from the Afterbay Damsite and 18-1/2 miles northwest from the Parks Bar Damsite. Ground cracks were found at several localities following the earthquake and aftershocks. Some were interpreted as having developed due to differential settlement caused by shaking. Others, such as the Cleveland Hill crack zone, are a result of the displacement along a pre-existing bedrock fault referred to as the Cleveland Hill fault. The crack zone is about 4 miles due east of the epicenter and consists of a pattern of well-developed en echelon, left-stepping fractures about 1-1/2 miles long (Plates IV and V). Offsets on the cracks indicate an oblique slip fault with normal and right lateral slip components of displacement presumably resulting from east-west crustal extension. There was a maximum of 1-1/2 to 2 inches of vertical and 1 to 1-1/2 inches of right lateral displacement (Hart and Rapp, 1975). Two other crack zones referred to as the Mission Olive crack zones, were discovered just north of the Cleveland Hill crack zone (Plates IV and V). They are roughly parallel, about 1,300 feet apart, and trend about due north for nearly 2 miles. They are similar to the Cleveland Hill cracks but are not as continuous (Akers and McQuilkin, 1975). Another area of numerous scattered ground cracks in unconsolidated sediments south of Palermo was named the Palermo crack zone (Plate IV). Aftershock hypocenters and focal depths indicate normal faulting, downdropped on the west side along a northwest-southeast trending fault dipping about 60° to 62° westward (Lester, Bufe, Lahr, and Stewart, 1975). According to Akers and McQuilkin (1975) the Cleveland Hill fault is probably the fault or one of the faults in a complex north trending zone of faults which are directly related to the Oroville earthquake sequence.

Until 1975, historical earthquakes in the surrounding area have not been accurately located because there was a lack of identified Quaternary faults, there was no clear association of earthquakes with mapped faults, and no surface ruptures were observed (Woodward-Clyde Consultants, April 1976). The closest significant historical earthquake was the

magnitude 5.7 earthquake on 8 February 1940, which originated about 50 miles north-northwest of the project area. The most significant earthquake from a more distant source was the magnitude 8.3 San Francisco earthquake of 18 April 1906 on the San Andreas Fault System. Its epicenter was approximately 115 miles southwest from the project area. The closest moderate-size earthquake occurred in the northern part of the Sierra Nevada Frontal Fault System which is located east of the Foothills Fault System and defines the eastern boundary of the Sierra Nevada structural block. That was the magnitude 6.3 Truckee earthquake on 12 September 1966. It reportedly was on the Russel Valley fault located about 65 miles east-northeast of the project area (Woodward-Lundgren and Associates, 1975). See the General Location and Fault Map.

The Oroville earthquake made it necessary to consider local earthquakes as well as strong distant sources in estimating the magnitude and recurrence interval for earthquakes that could affect the project. The distances between the project sites and strong distant earthquake sources would significantly attenuate seismic waves. The sparse historic record shows that only two moderate earthquakes have occurred within the northern region of the Foothills Fault System during the last 150 years, in 1940 and 1975.

According to Cramer and Taylor (California Division of Mines and Geology, 27-28 January 1977, personal communication) five portable microearthquake recording systems (seismographs capable of detecting earthquakes smaller than magnitude 3.0) recorded several events (M_L 3.0) from August to 4 September 1976 in the Lincoln-Auburn-Roseville area. Among those events were two pockets of 4 and 17 events recorded within the Rocklin Pluton, and two epicenters in the Marysville project area. In the project area the epicenters were plotted about 1 and 2 miles east of the Yuba River Damsite. The closest one, located inside Timbuctoo Bend had a magnitude of 1.0 and occurred at 1830 hours on 20 August 1976. The other, to the northeast across the Yuba River on Buzzard Peak, had a magnitude of 0.75 and occurred at 1100 hours on 2 September 1976. There was good north-south control for locating these epicenters but the east-west component could be about 3 miles off due to lack of seismograph stations in the area. The focal depths were estimated to be less than 6 miles (10 km).

In addition, three earlier instrumentally located epicenters plotted by several US Geological Survey permanent seismograph stations are located along the western margin of the foothills to the north and south of the Yuba River. Two of them are 9-1/2 and 10 miles northwest of the Yuba River Damsite. One in December 1975, had a magnitude of 0.7 and the other in early January 1976, had a magnitude of 1.3. Both were reported to be about 11 miles (18 km) in depth. The third epicenter

was about 6-1/4 miles south-southeast from the Yuba River Damsite. The earthquake occurred in May 1976, had a magnitude of 1.1 and a focal depth of about 9 miles (15 km). The seismologists checked these events against records for the Emma Scott quarry, located just east of Parks Bar bridge, and determined that no blasting was done at those times. These are very minor events and with the sensitive instruments used, similar events probably could be recorded very often throughout the foothills, especially over the Rocklin Pluton.

Methods for estimating probability of earthquake recurrence and likely ground motion intensities that could occur within the project area use the record of historical earthquakes and mathematical means relating to the linear extent of faulting and amount of displacement. Because of the relatively small number of earthquakes that have occurred within the northern area of the Foothills Fault System, estimates of recurrence intervals or magnitude for earthquakes associated with particular structural features must be regarded as having lower reliability than estimates for the entire region. Based on the historical record it appears that, even though past activity was mainly to the north of the sites, an earthquake with a magnitude on the order of 5.7 is possible within the area. Relating earthquake magnitude to fault length and displacement by using mathematical formulas and curves has many weaknesses or uncertainties because of mixing data from different kinds of faults, uncertainties about fault displacement through different kinds of geologic materials, and insufficient subsurface data on faulting. By applying the formulas and curves, a range of magnitudes on the order of 5.0 to 6.5 is possible.

In a report prepared for the Corps of Engineers by Professor Bruce A. Bolt of the University of California, Berkeley, it was concluded that the most severe earthquake motions likely to develop at the project area will be those due to either a local earthquake in the Foothills Fault Zone having a magnitude of about 6.25 and centered about 9 miles (15 km) from the Yuba River Damsite or an earthquake of magnitude 7.5 located on one of the faults on the west side of the Great Valley at a minimum distance of about 50 miles (80 km) from the project sites. They postulated a design earthquake with a magnitude of 6.25 which was used by Woodward-Clyde Consultants (October 1976) to evaluate the seismic stability of the proposed Parks Bar Afterbay Dam.

7. Areal geology. - The project area (Plate III) is underlain by bedrock consisting of probable late Jurassic metavolcanic rocks. They were originally mapped on the USGS folios as part of the Paleozoic "Western Belt of the Calaveras Formation" (Duffield and Sharp, 1975). The name Calaveras is no longer appropriate, and, although no definite stratigraphic correlations have been made, some of the rock may be correlative with the Oregon City Formation (Creely, 1965) to the north and the Gopher Ridge-Copper Hill Volcanics to the south (Duffield and Sharp, 1975; Clark, 1964, 1976). The metavolcanic rock types vary in composition from basic to acidic (basaltic, andesitic, and rhyolitic) and

have a wide variety of textures and structures. They primarily consist of pillowed to nonpillowed basaltic flows, andesitic to rhyolitic pyroclastics, and basic to felsic dikes. Many of the dikes are essentially the same composition as the flows and are probably feeders for them. The intrusive igneous bodies to the east and north of the project area vary in composition and include gabbroic, dioritic, and granitic rock types (Compton, 1955).

In and along the channel of the Yuba River, bedrock is overlain by deposits of recent alluvium and dredge tailings increasing in extent and amount downstream from Timbuctoo Bend toward Daguerre Point Dam and Hammonton. Scattered remnants and some larger areas of Tertiary and Quaternary terrace gravel deposits occur adjacent to the Yuba River and tributaries, and thicker deposits of worked auriferous gravels mantle higher elevations near Dry Creek Damsite, Sicard Flat, and Smartville. Auriferous gravels east of Sicard Flat and Smartville include deposits of pyroclastic volcanics. The extensive gravel deposits north and east of the Afterbay Damsite were partially excavated and worked for gold, exposing patches of the underlying fine grained sediments of the Eocene Ione Formation. Downstream from the damsite the gravels were also worked. West of Dry Creek and also south of the Yuba River near McCartie Hill, deposits of alluvium, terrace gravels, and Tertiary volcanics are not separated for this report. They are designated by the same symbol used for the Tertiary and Quaternary materials overlying the metavolcanic bedrock along the western margin of the map. Most contacts and symbols used to designate the geologic units on Plates I to V are the same as shown on the Geologic Map of California, Chico Sheet, 1962 (1:250,000 scale).

8. Description of bedrock units. - The state geologic map includes all of the bedrock in the project area under the symbol Δv designating Jurassic and/or Triassic metavolcanic rocks. In this report, the designation JV (Clark, 1976) is used. For this study bedrock units were separated into five broad groups of metavolcanic rocks with undetermined extent to the northwest and southeast (Plate III). These broad groups, designated A to E from west to east, are described separately below. Descriptions for the various rock types were collaborated with Buer (January 1977, personal communication) from unpublished Masters thesis notes.

a. Browns Valley Ridge to the regional shear zone. - Group A is a relatively thick, apparently undeformed, homoclinal, east-dipping sequence of intercalated pyroxene andesite tuff breccias, basaltic to andesitic porphyritic to uniformly fine grained flows, pyroxene pumice tuff breccia, and minor pillow-structured pyroxene andesite flows. This sequence is cut by a few basaltic to quartz dioritic dikes. Eastward, toward the shear zone, the flows are interlayered with relatively thin beds (5 to 50 feet) of finely laminated pyroclastic crystal and lithic tuffs and pyroxene tuff breccia.

b. Regional shear zone. - Rock throughout the shear zone is lithologically diverse, consisting primarily of actinolite, chlorite, clinozoisite, epidote, quartz and calcite schist. It has been subjected to low to medium grade dynamothermal metamorphism of the greenschist facies. The rock varies from massive to highly foliated and sheared showing later fracture cleavage. Relict structures indicate that the original rock units were primarily fine grained mafic tuffaceous debris, pillow- to nonpillow-structured flows, siliceous compacted and devitrified rhyolitic tuffs, agglomerates or tuff breccias, all of which were intruded by pyroxene porphyritic and diabasic dikes.

c. Regional shear zone to west of Parks Bar bridge. - Group C is a zone of complex structure (deformed and folded) consisting of pillow-structured basaltic flows, flow breccias, pyroclastic-layered crystal and lithic tuffs, and agglomerate or tuff breccia. Much of the agglomerates or tuff breccias contain interlayered pillowed flows and various types of fragmental volcanic materials such as amygdaloidal basalt and porphyritic rock types. This sequence appears to have been clastic deposits derived from the subaqueous extrusions to the east.

d. West of Parks Bar bridge to Deer Creek. - Group D is a thick sequence of basic to intermediate pillow- to nonpillow-structured flows and flow breccias with intercalated pillow breccias and layered tuffs cut by many diabasic to felsic dikes. A plutonic gabbro diorite to quartz diorite (granitic) igneous body occurs inside Timbuctoo Bend of the Yuba River. Bedding attitudes change throughout this area, suggesting an anticlinal structure trending northwestward through Timbuctoo Bend and a synclinal structure through Buzzard Peak, or the different attitudes may reflect local changes in direction of the volcanic flows. The contact between Groups D and E near the confluence of the Yuba River and Deer Creek and to the north is a fault or shear zone.

e. Deer Creek to Englebright Reservoir. - Group E is essentially a sheeted dike complex consisting of about 70 percent basaltic to felsic dikes which have intruded pillow-structured flows, flow breccias, and tuffs.

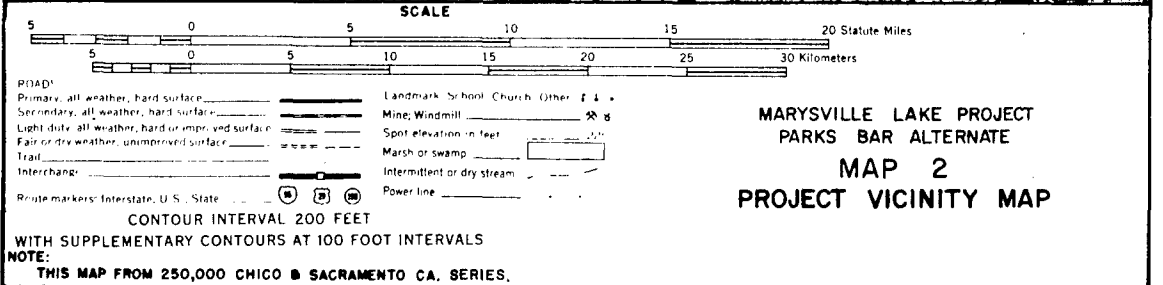
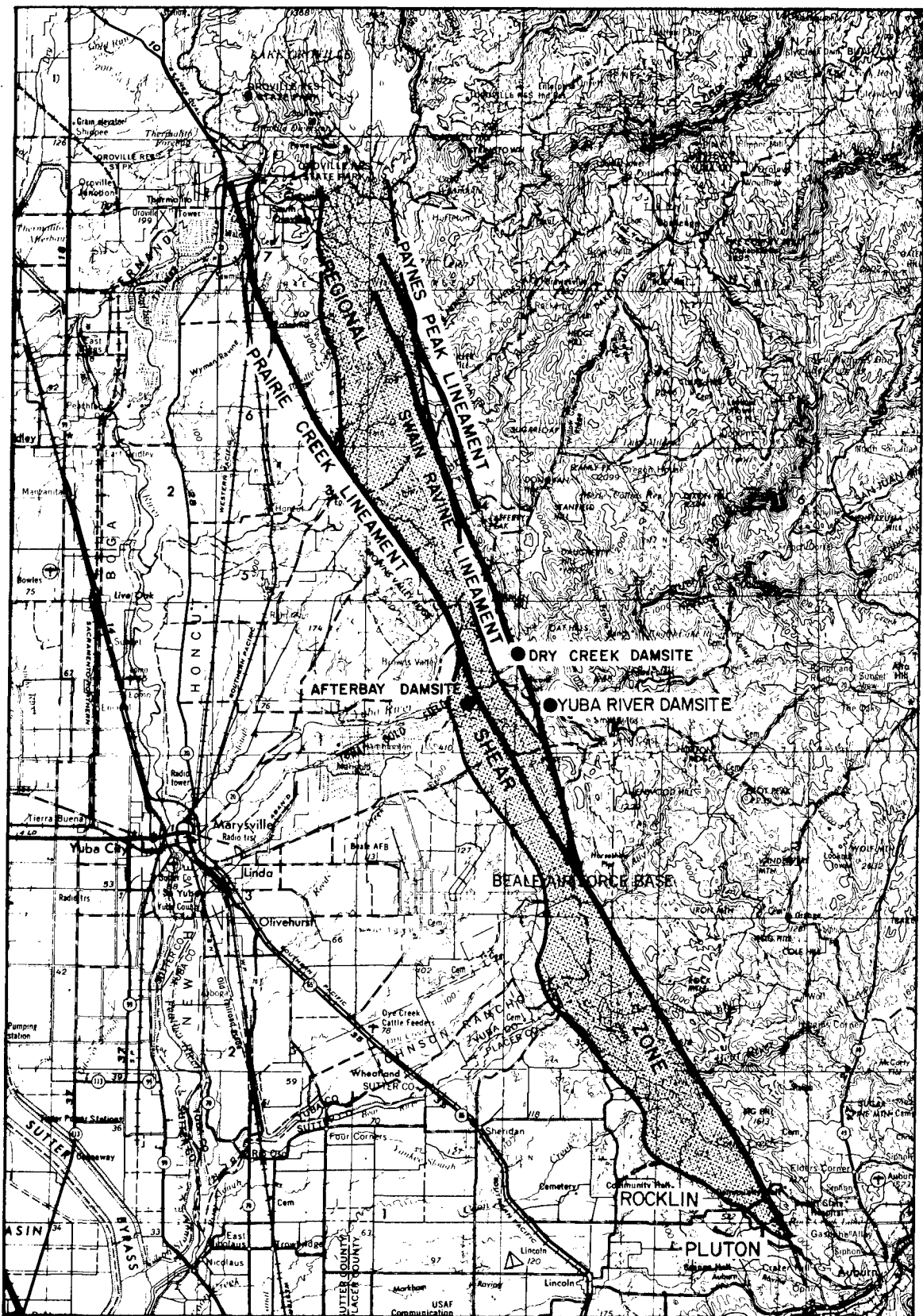
9. Structural features. - Attitudes of most structural features such as bedding, foliation (metamorphic rock cleavage), shears, and faults, generally parallel the N. 15° to 45° W. dominant structural grain of the foothills. From west to east along Highway 20, bedding dips 50 to 60 degrees eastward from Browns Valley Ridge to the regional shear zone, is nearly vertical through the shear zone, then, where recognizable, it dips 50 to 60 degrees westward to Timbuctoo Bend on the Yuba River (Plate III). In addition to the above features, several lineaments or prominent linear topographic trends of structural significance were identified and named from interpretation of low-sun-angle aerial photographs and aerial reconnaissance between Oroville and 6 miles south of the Yuba River.

The lineaments represent straight or gently curved features or a linear alignment of separate features showing linear geomorphic and topographic expression such as general continuous alignment of narrow valleys, well developed saddles, and in some areas the alignment of springs and seeps. Their general locations are shown on Map 2, Project Vicinity Map. Four of these lineaments, the Cleveland Hill, Paynes Peak, Swain Ravine, and Prairie Creek were defined in a report entitled, "Evaluation for Potential for Earthquakes and Surface Faulting, Parks Bar Afterbay Dam," which was prepared under contract for the Corps of Engineers after the Oroville earthquake (Woodward-Clyde Consultants, 1976). These lineaments are shown by a stippled pattern on Plates I to V. Portions of these features occur within, and portions occur outside of, the regional shear zone as it is shown on the Geologic Map of California; but all of them except the Prairie Creek lineament generally trend parallel to the structural grain of the region. The Cleveland Hill lineament is relatively short and projects southeastward into the Swain Ravine lineament. A crack zone marks the trace of the Cleveland Hill fault (Plates IV and V). The three other lineaments project toward or through the project area and, together with the regional shear zone, are briefly described from east to west.

a. Paynes Peak lineament. - The Paynes Peak lineament is a prominent feature that trends approximately N. 20° W. for about 10-1/2 miles. It is shown on Plates IV and V extending from the northeast side of Cleveland Hill to about 4-1/2 miles southeast of Bangor in the vicinity of Stone House north of Johnson and Paynes Peaks. The topographic expression of this lineament continues southeastward from there along the west side of Holman Hill, through the Forbes Ranch and the upstream segment of Timbuctoo Bend, but structural relationships were not identified in the field.

b. Swain Ravine lineament. - The Swain Ravine lineament roughly parallels the Paynes Peak lineament and is prominent for about 23 miles on a bearing of N. 20° to 25° W. (Plates II, III and IV). It passes through Dry Creek Damsite and crosses the Yuba River about 2,500 feet west (downstream) of the Parks Bar Damsite. About 7.3 miles south of the Yuba River (Plate II) it is apparently truncated by the Prairie Creek lineament, and 15.7 miles north of the river it projects into the southeast end of the Cleveland Hill fault. Most of the lineament south of the Yuba River coincides with the eastern boundary of the regional shear zone.

c. Regional shear zone. - As noted in the description of bedrock units, the rock in the shear zone is lithologically diverse, and the structure is not well understood. It varies from massive to highly foliated and sheared, and bedding attitudes vary from vertical to steeply dipping to the southwest or northeast. The shear zone boundaries appear to be gradational rather than sharply defined. In the



project area (Plate III), the west boundary of the shear zone as shown on previous geologic maps was extended to the west to the junction of Dry Creek and the Yuba River, thus including the Afterbay Damsite within the zone.

d. Prairie Creek lineament. - The Prairie Creek lineament is the longest lineament in the area. It cuts across the structural trend of the regional shear zone on a bearing of approximately N. 30° W. (Plates I to V). The lineament coincides with part of the western boundary of the shear zone north of the Yuba River and has continuity through the Afterbay Damsite to the vicinity of Wellman Creek. It is in line with the Palermo crack zone and with faults in the Pliocene Tuscan Formation north and east of Chico; it projects southeastward from Wellman Creek through Austin Ravine and through the mile-long jog in Bear Creek and continues along the eastern boundary of the shear zone to the Rocklin Pluton. The total length of the Prairie Creek lineament was not determined, but it is about 48 miles from Oroville to the Rocklin Pluton. About 45 miles of the lineament is shown on Plates I to V.

10. Geologic and seismic investigations. - Prior to the 1 August 1975 Oroville earthquake, the Pacific Gas and Electric Company was conducting a seismic investigation of the Foothills Fault System for location planning of nuclear powerplants. Also, a report entitled, "Geology, Seismicity, and Faulting and Evaluation of Seismic Stability, Marysville Dam," 1975, was prepared for the Corps of Engineers by Woodward-Lundgren and Associates for the Marysville project Browns Valley site. After the Oroville earthquake, two additional reports were prepared for the present Marysville project: "Evaluation for Potential for Earthquakes and Surface Faulting, Parks Bar Afterbay Dam" and "Evaluation of Seismic Stability, Parks Bar Afterbay Dam" (Woodward-Clyde Consultants, April 1976 and October 1976).

Immediately after the Oroville earthquake, the California Department of Water Resources investigated the surrounding epicentral area and the Oroville Dam area for evidence of ground cracking and surface faulting. Three known faults west of the dam were also inspected but no evidence of recent movement was found (Akers and McQuilkin, 1975). Other contributions consisted of seismological investigations by the US Geological Survey and the initiation of additional geological mapping by the California Division of Mines and Geology. Information from these studies was compiled in Special Report 124 by the California Division of Mines and Geology (Sherburne and Hauge, 1975). The Pacific Gas and Electric Company and the California Department of Water Resources investigated the many reported isolated cracks and zones of ground cracks which have become known as the "Palermo", the "Mission Olive", and the "Cleveland Hill" crack zones (Plates IV and V).

11. Investigations outside of the project area. - Subsurface explorations of the Cleveland Hill and Mission Olive crack zones and the Paynes Peak,

Swain Ravine, and Prairie Creek lineaments were done at various times and places. A total of 46 trenches was excavated by four separate agencies from August 1975 to November 1976 in addition to the 5 trenches in the project area for this study. The trenches listed here are categorized firstly by the feature they investigate and secondly by the agency they were done for.

a. Cleveland Hill crack zone (six trenches).

(1) DWR In August 1975 the California Department of Water Resources excavated three trenches designated A, B, and D across the crack zone. Trench C was started but not completed due to sloughing of trench walls. These were the first trenches in the area to investigate ground cracks resulting from the Oroville earthquake. Their locations are shown on Plate IV. They exposed a pre-existing fault (probably Jurassic) with a wide clay gouge zone and brecciated rock directly beneath the surface cracks. However, the cracks could not be traced from the surface into the bedrock, fault or gouge zone, and there was no evidence of bedrock displacement (Akers and McQuilkin, 1975).

(2) USCEC In January 1976 the Corps of Engineers excavated two trenches, designated Cleveland Hill Nos. 1 and 2, across the crack zone (Plate V). These trenches exposed bedrock fault zones directly beneath or near surface cracks and showed evidence of at least three separate episodes of small scale fault displacements totalling 18 inches. They were estimated to have occurred within the range of 5,000 to 100,000 years based on the estimated age of the soil profile (Woodward-Clyde Consultants, April 1976).

(3) PG&E In March 1976 the Pacific Gas and Electric Company excavated one trench, Cleveland Hill No. 3 at the location shown on Plate IV. Results were similar to what was found in DWR trenches A, B, and D.

b. Mission Olive crack zones (16 trenches).

(1) USCEC In January 1976 the Corps of Engineers excavated one trench, Grubbs No. 1, across the crack zone (Plate V). Results were comparable with the Cleveland Hill Nos. 1 and 2 trenches.

(2) PG&E From March to May 1976 the Pacific Gas and Electric Company excavated five trenches designated Sims No. 1, Lorraine Nos. 1, 2, and 3, and Grubbs No. 2 across the crack zone (Plate V). Results of these trenches were essentially the same as for the Cleveland Hill Nos. 1 and 2, and Grubbs No. 1 trenches.

(3) DWR In May 1976 the California Department of Water Resources excavated seven trenches across photo lineaments and ground cracks that extend northward along the crack zone from Cleveland Hill toward the

Bidwell Bar arm of Lake Oroville (Plate V). These trenches are a northward continuation from trenches A to D but are numbered 5, 7A, 7B, 8, 9, 10, and 11. Trench No. 6 was started but was not completed because of deep alluvium and excessive inflow of ground water. Three of these trenches (5, 7A, and 8) exposed fault structures which correlated with lineaments or surface cracks. No evidence of recent movement was found in Nos. 5 and 7A, but in No. 8 there was evidence for about 1/2-inch of displacement prior to the 1 August 1975 earthquake. In October and November 1976 the DWR excavated three additional trenches, Nos. 12, 13, and 14, which were located between Nos. 8 and 10. Bedrock shear and fault features exposed had essentially the same relationship to ground cracks and lineaments as in trenches to the south. No evidence of recent movement was found (Akers, personal communication).

c. Paynes Peak lineament (three trenches).

PG&E In March 1976 the Pacific Gas and Electric Company excavated three trenches designated Knapp No. 1, about 1/4-mile southwest of Bangor and Burt Nos. 1 and 2 about 2 miles south of Bangor along the lineament (Plate IV). Burt No. 2 trench was only a few feet long and was located a few feet south of the No. 1 trench to inspect the fault structure exposed in the No. 1 trench. Bedrock shear and fault structures were exposed but none of the features extended upward into overburden materials and no evidence of recent movement was found.

d. Swain Ravine lineament (13 trenches).

(1) PG&E In March 1976 the Pacific Gas and Electric Company excavated five trenches, designated Pace Nos. 1 to 5, across the lineament about two miles northeast of Loma Rica (Plate IV). The trenches ranged from 22 to 270 feet in length, covered about 550 feet of ground surface, and were located on a N. 65° E. alignment. One fault structure with clay gouge and several shear structures were exposed, but none of those bedrock features extended upward into the overburden materials and no indication of recent movement was found.

(2) USBR In July and August 1976 the US Bureau of Reclamation excavated eight trenches, designated Orange Avenue trenches A to H, in an area with several ground cracks along the lineament about 1-1/2 miles northwest of Bangor (Plate IV). The exact location of all trenches is not available at this time, but trenches A to D are known to be within the circle shown on the map. Trenches excavated across surface cracks showed the same relationship to bedrock fault structures that was found to the northwest at Cleveland Hill. In some of the trenches, bedrock shears and faults reportedly offset Cenozoic alluvial deposits and metavolcanic bedrock (USBR, personal communication).

In trench C, a fault with 13 to 14 feet of displacement was reportedly substantiated by data obtained from the drilling of two NX diamond core holes. Details and final conclusions for these trenches are not available at this time but will be included in a report by the Bureau.

e. Prairie Creek lineament (eight trenches).

(1) PG&E In March 1976 the Pacific Gas and Electric Company excavated two trenches, designated Wilson Nos. 1 and 2, across a portion of the lineament about three miles northwest from Browns Valley (Plate III). Trench No. 2 was only a few feet long and was excavated a few feet south of the No. 1 trench to inspect the fault structure exposed in the No. 1 trench. A bedrock fault structure with clay gouge was exposed, but no part of it extended upward into overburden materials and no indication of recent movement was found.

Sometime before May 1976 a second location, designated O'Brien No. 1, was trenched. It was located two miles northwest of Loma Rica (Plate IV). At that location no major bedrock fault or shear feature was exposed.

(2) USBR In August and September 1976 the US Bureau of Reclamation excavated five trenches designated Spenceville Nos. 1 to 5 across the Prairie Creek lineament about 8-3/4 miles southeast of the Parks Bar Damsite and three miles north-northeast of Camp Far West Reservoir (Plate II). The trenches exposed several southwest dipping shears and a bedrock fault structure with a wide clay gouge zone. In trench No. 1 the fault strikes N. 45° W. and dips 65° SW. According to the consultants logging the trenches for the Bureau, at least one of several individual slickensided shear planes within the fault gouge extends upward into, and apparently offsets the base of an overlying paleosol of undetermined age. The consultants have indicated possible recent movement on this fault although apparently very small (USBR, personal communication).

12. Investigations by the Corps of Engineers for this study. Extensive geological field mapping and subsurface exploration by trenching was done by the Sacramento District. Also, trenches excavated by other agencies were inspected, and findings in this investigation were continually compared with those from other investigations.

a. Geological mapping. From February to May 1976 geological field mapping was concentrated on the Marysville project area (Plate III). The area surrounding the project components was investigated entirely on foot. The various rock types and attitudes of structural features were located and plotted on appropriate maps, and the metavolcanics were tentatively separated into broad mappable lithologic groups. The lineaments and regional shear zone boundaries were traced through

the project area, and a thorough search was conducted for evidence of ground cracks and recent surface faulting.

In May 1976, geologic reconnaissance mapping was done throughout most of the regional shear zone extending from a few miles northeast of Lincoln to Lake Oroville. Numerous traverses were made along roads crossing the shear zone. This mapping was done primarily to verify the location and extent of the shear zone and to correlate rock types to the north and south with those found in the project area. Mapping data were plotted in the field on USGS 7-1/2 minute quadrangle maps (scale 1" = 2,000'), special project orthophoto maps at scales of 1" = 200' and 1" = 400', and aerial photographs at a scale of 1" = 500'. Final compilation of data was done on base maps made from USGS 7-1/2 minute quadrangle maps.

b. Trenching. From 2 June to 8 July 1976 a series of five trenches, about 32 inches wide and ranging from 104 to 350 feet in length were excavated to depths of 3 to 9 feet perpendicular to and across the alignment of the Swain Ravine lineament northwest and southeast from Dry Creek Damsite. The trenches were designated 4F-1 to 4F-5. Their locations are shown on Plate III, and the trench logs are shown on Plates VI through XI.

All the trenches were field located along the trend of the Swain Ravine lineament as based on geologic structural features exposed at the surface. Those features included a bedrock fault, zones of highly foliated rock, and topographic saddles. The lengths of trenches at the selected localities were designed to cross all structural features indicated at the ground surface. Trenches were extended during excavation until relatively massive, nonfoliated or non-sheared bedrock was encountered. Bedrock and soil features observed in the south wall of each trench were logged at a scale of 1 inch equals 2 feet. Each trench, with its pertinent features, is described below.

(1) Trench 4F-1 (Plate VI). Trench 4F-1 was located in a topographic swale about 1,300 feet west of Peoria Road and 500 feet southeast of a small reservoir. It was excavated on 2 June and backfilled on 11 June 1976. The trench was approximately 32 inches wide, 8 to 9 feet deep and was 133.5 feet long on a bearing of N. 63° E. The trench was located to cross the lineament where a fault, exposed in a gully southeast from the reservoir spillway, projects on strike and dip to the center of the swale. The exposed fault is sinuous but generally strikes N. 40° E. and dips 65° SE. It corresponds, with a slight attitude change, to fault 4F-1A which strikes N. 50° W. and dips 41° NE.

The trench cut exposed 0.4 to 3.6 feet of colluvium (overburden) consisting of organic soil and slopewash overlying weathered bedrock.

Thickness of the colluvium increases toward the center of the trench. The contact between the colluvium and weathered bedrock is an irregular erosional surface with about one foot of relief. About 0.5 foot or less of the upper part of weathered rock, at scattered locations, is residual soil which grades indistinctly into material below with rock texture. Residual soil was not separated from weathered bedrock on the trench log. Bedrock consists of metavolcanic agglomerate. The entire trench, except for the first 2 feet and the last 3-5 feet, consisted of decomposed to highly weathered bedrock, with some zones exhibiting well developed spheroidal weathering structures. Joints and spheroidally weathered surfaces are stained brown to dark reddish brown by iron oxide. The rock is locally sheared or foliated and altered. Bedding was not discernable. Pyroclasts (or fragments) are elongated parallel to the foliation between 62 and 134 feet along the trench.

The significant structural features include faults, foliation, shears, and joints, some of which have altered coatings.

(a) Faults. The major structural features were two subparallel faults, 1.8 to 3.0 feet apart, located between 53 and 62 feet along the trench. The eastern fault, designated 4F-1A, strikes N. 50° W. and dips 41° NE. The western fault, designated 4F-1B, strikes N. 15° W. and dips 47° NE. Light gray to light grayish green, moist, highly plastic clay gouge occurred on both faults. Thickness of the gouge increased upward from 0.1 foot at the trench bottom to 0.6 foot on 4F-1B and 1.4 feet on 4F-1A near the slopewash-bedrock contact, but there is no evidence that the gouge or shearing extends into the overburden, and no displacement is apparent. Shears and foliation between faults 4F-1A and 4F-1B and adjacent to the east side of fault 4F-1A trend from parallel to the faults at the trench floor to steeper in the up-dip direction and become overturned, dipping 67° to 86° SW at the slopewash-bedrock contact.

(b) Foliation and shears. Moderately to highly foliated rock with numerous sheared zones and thin shear planes occurs from 50 to 104 feet. The rock is slightly to moderately foliated with scattered thin shears from 104 feet to the end of the trench at 133.5 feet. Where the original rock texture was not destroyed, pyroclasts or fragments are elongated parallel to the foliation. The attitudes of shearing changes from east to west.

Along with the shearing on the southwest side of fault 4F-1B, drag folds at 60.6 feet indicate normal movement for the fault, downropped on the east side.

(c) Joints. Throughout the trench the rock is moderately to highly jointed with spacing from 1/4 inch to 5 inches, giving the rock a blocky fractured appearance. From 0 to 50 feet along the trench the rock is

massive, but apparent small scale displacements have disturbed or shifted the rock along joint planes east of the faults. Joint surfaces are mostly coated with yellowish brown to brownish red iron oxide stains. Several joints appear to have coatings of altered laminated siliceous material, probably epidote, quartz and calcite from 1/2 inch to 2 inches thick. Some of the coatings are hard, altered light grayish green siliceous material; and some are a dull white to salmon pink altered material consisting mostly of silt or clay. Numerous joints were measured but most were too short and discontinuous to be shown on the trench log. The attitudes of five joint sets are as follows:

<u>STRIKE</u>	<u>DIP</u>
N. 50° to 60° E.	80° NW. to vertical
N. 30° to 20° W.	24° to 76° NE.
N. 27° to 43° W.	70° NE. to vertical
N. 24° to 31° W.	70° to 80° SW.
N. 30° to 42° W.	35° to 65° SW.

(2) Trench 4F-2 (Plate VII). Trench 4F-2 was located in the channel area of Dry Creek immediately east of Peoria Road. The location was 200 feet southwest from the intersection of Peoria and Township Roads and 300 feet northwest from the bridge over Dry Creek. It was excavated on 3, 4, and 7 June and backfilled on 21 June 1976. The trench was approximately 32 inches wide, 7 to 9 feet deep and was 174.0 feet long on a bearing of N. 58° E. This locality was selected because of a 150-foot-wide zone of foliated rock exposed in a small side branch of the main Dry Creek channel. This appeared to be the most likely area to cross features of the Swain Ravine lineament because the bedrock is massive westward from Peoria Road and also eastward from the left abutment of Dry Creek bridge.

The trench cut exposed 1.0 to 8.2 feet of overburden (alluvium) consisting of stream deposited flood plain material and underlying sand and gravel lenses over bedrock. The flood plain deposit varies from 0.3 to 3.2 feet thick and the sand and gravel is from 0.1 to 7.0 feet thick. A maximum of 3.2 feet of bedrock was exposed at any one location in the trench. Stream erosion, prior to deposition of the alluvium, produced a bedrock surface with about 3 feet of relief. The contact between bedrock and alluvium is sharp with no residual soil separating the two units. The rock varies from nearly fresh to highly weathered, some spheroidally weathered, and from massive to highly foliated. Numerous zones of very soft, clayey, altered rock occur between 36 and 146 feet along the trench. Clay seams and clayey zones of weathered rock are common. Bedding was not discernible.

Significant features include altered rock, foliation, shears, and joints. No faults were found in the trench.

(a) Altered rock. The rock grades laterally in and out of soft, mostly white, clayey altered rock and harder less weathered grayish-green unaltered rock with no apparent structural features associated with the alteration. No evidence of faulting, shearing, or intrusive bodies was found which could have produced the alteration. This alteration could be a weathering phenomenon which is characteristic of the particular conditions and tuffaceous rock type, whereby acid solutions produced from weathering of the disseminated pyrite bleaches the material as it is weathered. Subsequent iron oxide staining produces streaks along pre-existing structural features such as foliation planes. Some contacts between altered rock and hard, slightly weathered rock are sharp but others are gradational.

(b) Foliation and shears. Most of the rock throughout the trench is foliated in degrees varying from slight to intense. Attitudes of foliation ranges from strikes of N. 12° E. to N. 31° W. and dips of 66° SE. or NE. to vertical. One zone of intense foliation or shearing occurred between 166.6 and 171.5 feet along the trench in association with clay seams of the same attitude which dip steeply northeast.

(c) Joints. Not many distinct or regular joint planes were exposed in the trench probably due to the weathered condition of the rock. Most of the joints noted were nearly parallel to the foliation. The few joints measured ranged from strikes of N. 2° W. to N. 12° E., and dips of 66° SE. to 72° NE. In general, rock throughout the trench was moderately jointed with surfaces iron oxide stained and/or clay coated.

(3) Trench 4F-3 (Plate VIII). Trench 4F-3 was located parallel to and about 40 feet north of Sicard Flat Road. The west end was 450 feet east of the intersection of Sicard Flat and Peoria Roads and about 30 feet east of Smith ditch. It was excavated on 8 and 9 June and back-filled on 8 July 1976. The trench was about 32 inches wide, 3.0 to 7.5 feet deep and 104.2 feet long on a bearing of N. $76\frac{1}{2}^{\circ}$ W. This locality was selected as part of the area to be trenched because the Swain Ravine lineament passes through the wide valley bottom. Trench 4F-3 would have been 500 \pm feet long (including the location of Trench 4F-4) if the area had not been traversed by the Smith ditch. Moderately to highly foliated rock was noted in the ditch bank on the north side of Sicard Flat Road from near the intersection with Peoria Road and eastward for almost 500 feet.

The trench cut exposed 0.4 foot to 2.5 feet of overburden and 1.3 to 6.8 feet of weathered bedrock. The overburden consists of organic soil, slopewash and residual soil. The residual soil occurs only between 55.0 and 104.2 feet along the trench. The rock exposed in the first 60 feet of trench varies from highly weathered to decomposed, moderately to highly foliated, sheared, and altered; from 60.0 to 104.2 feet the rock is mostly massive, although moderately to highly weathered. Several

dikes, thin shears, fractured quartz seams, and one fault were exposed. The contact between slopewash and residual soil or weathered rock represents an erosional surface with as much as 0.8-foot of relief.

Significant features include foliation and shears, joints, one fault, and dikes.

(a) Foliation and shears. Highly foliated, sheared and altered rock occurred from 0 to 60.0 feet except for massive dikes. Scattered thin shears occur from 60.0 to 104.2 feet. Shear planes range from strikes of N. 10° E. to N. 27° W. and dips of 52° to 75° eastward or vertical. Foliation generally ranges from strikes of N. 15° E. to N. 20° W. and from dips of 55° to 80° eastward or westward. Rock beneath the fault is highly sheared and broken at an attitude of N. 15° W., 60° NE.

(b) Joints. Joints are abundant but short and discontinuous and could generally be traced for only 2 to 3 feet. A few joints had slickensided coatings, generally less than 1/16 inch thick, consisting of altered or weathered calcite, epidote, and quartz. Major joint sets strike N. 60° E. to N. 26° W. and dip 76° to 80° NE. to SE. and 20 - 30° SW.

(c) Fault. One fault, striking N. 15° W. and dipping 46° NE. is located between 16 and 22 feet along the trench. The fault is a straight planar feature which truncates part of a dike at the bedrock-slopewash contact and is coated with light greenish gray clay gouge varying from 0.1-foot thick at the trench floor to 0.3-foot thick at the bedrock-slopewash contact. The contact shows no offset and there is no evidence to suggest the relative direction of movement on the fault. Also, there is no evidence that shearing extends into the overburden.

(d) Dikes. Six dikes ranging from 0.2 foot to 10.0 feet wide are spaced about 6 to 22 feet apart throughout the trench. They consist of massive, moderately to highly jointed, unaltered, moderately to highly weathered, iron oxide stained rock. The texture is a uniformly fine grained groundmass with scattered 1/8-inch phenocrysts. The two larger dikes, from 2.0 to 7.5 feet and 59.0 to 70.0 feet, have associated 1/2- to 4-inch-wide quartz seams. Two dikes 1-1/2 feet wide between 23.0 and 35.5 feet have thin dikelets extending between them and westward to about 47.0 feet. "Baked zones" occur along dike-country rock contacts at 22.0 and 59.0 feet. The dike at 36.0 feet has chilled margins on both sides. Two small dikes, 0.1 to 0.6 foot wide occur at 75.0 and 87.0 feet with no associated quartz veins or dikelets and no noticeable baked zones or chilled margins. Attitudes of the dikes range from strikes of N. 40° W. to N. 15° E. and dips of 60° to 85° NE. and 42° SE. to vertical. They trend predominantly northwest and dip northeast. Contacts between the dikes and adjacent rock are generally sinuous or irregular.

(4) Trench 4F-4 (Plates IX and X). Trench 4F-4 was located 50 feet west of Trench 4F-3 on the same alignment, about 20 feet west of Smith ditch. It is parallel to and about 40 feet north of Sicard Flat Road and extends westward to within 35 feet of Peoria Road. It was excavated between 8 and 11 June and backfilled on 7 and 8 July 1976. The trench was excavated about 32 inches wide, 3.8 to 7.1 feet deep, and 349.8 feet long on a bearing of N. 76-1/2° W. This locality was selected for trenching because the precise location of features comprising the Swain Ravine lineament could not be determined. Moderately to highly foliated rock exposed on the north side of Sicard Flat Road from near Peoria Road to about 500 feet eastward suggested the location of the lineament.

The first 340.0 feet of the trench cut exposed 0.4 to 3.9 feet of overburden consisting of organic soil, slopewash, and residual soil. From about 327.0 feet, bedrock was eroded on a moderately steep westward slope that projects beneath the trench floor at 340.0 feet. Probably in late Tertiary or early Quaternary time the bedrock slope was mantled by stream alluvium. Overburden, consisting of slopewash and older alluvium, is 5.2 feet thick at 340.0 feet and it increases in thickness westward toward Dry Creek. Since deposition of the alluvium, two soil layers have developed from the alluvium and are in turn overlain by slopewash. Throughout the trench, the contact between the slopewash and residual soil or weathered bedrock represents an erosional surface with less than one foot of relief except at 198.0 feet and on the erosional slope from 327.0 to 340.0 feet. Beneath the slopewash from about 276.0 to 303.0 feet a layer of fine grained clayey soil, possibly alluvium, overlies bedrock. The thickness of organic soil increases from 0.1 to 0.3 foot at the east end of the trench and to about one foot at 145.0 feet. From 145.0 feet organic soil is not a separate unit and is mixed with slopewash of various descriptions. Residual soil is a continuous unit from 0 to 131.5 feet, then occurs only in scattered pockets and short intervals from 166.0 to 319.0 feet.

Bedrock consists of various metavolcanic rock types including agglomerate, tuff, and tuff breccia. Most bedrock exposed is soft to moderately soft and varies from moderately to highly weathered and iron oxide stained. About half of the bedrock is massive and half is moderately foliated. Contacts between massive and foliated rock are generally gradational. Some of the rock is altered as in Trench 4F-3. The contact between bedrock and overlying residual soil is very uneven with as much as two feet of relief. This is apparently the result of differential weathering, although the reasons are not clear. It does not appear to have any relationship to rock structure including either of the bedrock faults.

Significant features include foliation, joints, and faults.

(a) Foliation. Moderately foliated rock occurs at intervals throughout about half of the trench. A zone of slightly foliated rock occurs

between 193 and 223 feet. Attitudes range from strikes of N. 20° W. to N. 30° E. and dips of 60° to 75° NE. or SE., and vertical.

(b) Joints. Joints were abundant but short and discontinuous as in Trench 4F-3. The range in attitude of major joint sets tabulated below.

<u>STRIKE</u>	<u>DIP</u>
N. 15° to 80° E.	20° to 30° SW.
N. 10° E.	35° SE.
N. 47° to 77° E.	Vertical
N. 10° to 52° W.	40° to 67° SW.
N. 25° to 45° W.	27° to 85° NE.

(c) Faults. Two bedrock faults were found in Trench 4F-4. One, designated 4F-4A, occurs at 34.5 feet and the other, 4F-4B, at 320.0 feet. Fault 4F-4A strikes N. 2° E. and dips 52° SE. It has 0.2 to 0.6 foot of clay gouge. Fault 4F-4B is a much larger feature. It strikes N. 22° W. and dips 48° SW. On the south trench wall it has 0.5 to 1.0 foot of clay gouge and on the north wall there is about 0.5 foot to 2.2 feet of gouge. Shearing does not extend into the overlying soil, although the residual soil is thicker adjacent to Fault 4F-4A. However, there are numerous other places with similar conditions, and the thickened soil is believed to be related to differential weathering. The relative direction of movement could not be determined for either fault.

(5) Trench 4F-5 (Plate XI). Trench 4F-5 was located in a topographic saddle north of Sicard Flat. The northeast end of the trench was 152 feet N. 76° W. from the northwest end of the siphon that crosses Sicard Flat Road. The trench was excavated on 14, 24, and 25 June and backfilled on 8 July 1976. It was about 32 inches wide, had a maximum depth of 7.6 feet, and was 168.2 feet long on an average bearing of N. 67° E. Short segments of the trench varied from bearings of N. 62° E. to N. 81° E. Structural evidence of geological features related to the Swain Ravine lineament consists only of topographic saddles or swales with very few rock outcrops between fairly large, massive, hard rock outcrops.

The trench cut varied from 0.3 to 7.6 feet deep and exposed 0.3 to 6.0 feet of overburden materials overlying 0.2 to 4.5 feet of weathered bedrock. Overburden materials consist of organic soil, slopewash, and residual soil. The organic soil layer is fairly uniform throughout the entire trench and is 0.1 to 0.3 foot thick. Slopewash occurs throughout the trench, varying from 0.2 to 2.3 feet thick. Residual soil, varying from about 0.2 to 4.5 feet thick, occurs in most of the

trench except in an area of hard, near-surface bedrock at trench location 15.0 to 20.0 feet and in areas where it was probably removed by erosion at 39.0 to 42.0 feet and 138.0 to 168.2 feet. One small isolated pocket of residual soil is at 148.5 feet. The contact between residual soil and bedrock is irregular, probably a reflection of differences in the parent rock's resistance to weathering. The erosional surface between residual soil and the overlying slopewash is fairly uniform, conforming to the general surface topography with less than 1.0 foot of relief.

From 0.2 to 4.7 feet of bedrock was exposed beneath the overburden materials. It consists predominately of metavolcanic agglomerate. The rock varies from light grayish green and greenish brown to brownish tan and tan. It is soft to hard, varies from slightly weathered to highly weathered or decomposed, most of it exhibits spheroidal weathering structure, and it is moderately to highly jointed. Bedding attitude was not discernable in the trench. One hard, slightly weathered rib of rock occurs from trench location 15.0 to 20.0 feet; and soft, highly weathered or decomposed and altered rock occurs between 92.0 and 111.4 feet in a fault and shear zone. Two other minor thin shears occur between 24.0 and 26.0 feet. Except for minor thin shears and two fault and shear structures bracketing the fault and shear zone, the rock is massive. No zones of foliated rock were exposed.

Significant features include a fault and shear zone, minor thin shears, and joints.

(a) Fault and shear zone. A fault and shear zone occurs between 92.0 and 111.4 feet. The zone is bounded on the northeast side by feature 4F-5A and on the southwest by feature 4F-5B. Feature 4F-5A consists of at least 3 fault or shear planes with attitudes of N. 32° W., 70° NE., N. 34° W., 70° SW.; and N. 42° W., 48° NW. Approximately 0.1-foot of damp, light tan, moderately to highly plastic clay gouge with small angular rock fragments occurs on the N. 32° W., 80° NE. plane. Above the plane, closely spaced curving fractures may represent drag features produced by movement along the plane. Also, the plane appears to terminate indistinctly upward into the decomposed rock and does not penetrate the overlying soil. The thickness of residual soil is greatly increased directly above the N. 34° W., 70° SW. plane, probably a reflection of the sheared rock's susceptibility to weathering. All of the features of 4F-5A are fairly indistinct and no clear relationship between them was apparent. It appeared that the rock has been shifted around, and joints and shear planes offset and truncate each other. Feature 4F-5B strikes N. 27° W. and dips 75° NE. It is a thin plane that could be either a shear or fault plane. There is no clay gouge along the plane and no sense of movement was discernible. There is no evidence of displacement in the soil overlying bedrock in either structure.

(b) Minor thin shears. Two thin southwestward dipping shears occur between 24.0 and 26.0 feet. They are fairly indistinct features that do not extend upward to the top of bedrock or downward to the bottom of the trench. A few other thin shear planes occur in the middle of the fault and shear zone between 99.0 and 104.0 feet. These features all strike from north to N. 27° W. and dip 46° to 86° SW. None of them extend through the decomposed bedrock to the residual soil.

(c) Joints. Joints are abundant but short and discontinuous. Most are stained brownish red by iron oxide and a few are thinly coated with laminated calcite, epidote, and quartz. Throughout the trench the rock is too weathered for measuring joint attitudes except for general direction of dip. The dips vary from 55° to 85° eastward to about 150.0 feet, are vertical to about 152.0 feet, and then are 70° to 75° westward to the end of the trench at 168.2 feet.

(6) Trenching summary. The trenches exposed weathered rock varying from massive to slightly, moderately, and highly foliated or sheared. Much of the rock is variably altered and shows evidence of complex structural deformation over a zone up to several hundred feet wide. There are many scattered bedrock structures including thin shears, shear zones, and several fault structures with different attitudes, which cannot be dated except that they are Upper Jurassic age or younger. Seven bedrock faults were identified in five trenches and six of them have clay gouge ranging from 0.1 to 1.4 feet in thickness. The gouge zones generally are thicker at the bedrock-soil contact than at the trench floor. Individual shear planes were not found within the gouge zones. There is no evidence apparent to suggest that fault-related structures extend upward into overlying overburden materials, and no evidence was found of Recent or even Quaternary fault movement. Attitudes of five of the seven faults found ranged from strikes of N. 5° to 32° W. and dips of 41° to 75° NE. One fault strikes N. 2° E. and dips 52° SE., and the only identified westward dipping fault strikes N. 22° W. and dips 48° SW. Insufficient structural relationships precluded determination of the relative direction of fault displacement except in Trench 4F-1. There, drag fold structures indicated normal movement, down on the east side, for two subparallel faults striking N. 5° to 15° W. and dipping 41° to 47° NE.

13. Summary of the study. This fault evaluation study contributes to a better understanding of the geology and structural relationships throughout the regional shear zone extending from the Rocklin Pluton northward toward Lake Oroville. Reconnaissance geological mapping and detailed mapping in the Marysville project area showed that similar rock types with complex structure and limited lateral continuity occur throughout the area. The metavolcanic bedrock in the project area was separated into five broad lithologically and structurally definable groups from west to east.

During the study, rock types and geologic structures were identified and mapped, the regional shear zone boundaries and major structural lineaments were traced out and delineated on maps, the project area was thoroughly searched for any evidence of ground cracks and recent surface faulting, and subsurface exploration by trenching was conducted. Five trenches, designated 4F-1 to 4F-5, were excavated along the Swain Ravine lineament about 1 to 4 miles northwest of the Yuba River. The Swain Ravine lineament is significant to the Marysville project because it is a prominent, nearly straight structural feature that crosses the Yuba River about 2,500 feet west of the Parks Bar Damsite, passes through the Dry Creek Damsite and projects northwestward into the southeast end of the recently active Cleveland Hill fault. Trenching across ground cracks on the Cleveland Hill fault showed evidence of at least three episodes of small displacements totalling about 18 inches within Quaternary time. The Swain Ravine lineament has strong continuity for about 23 miles on a bearing ranging from N. 20° to 25° W. (averages N. 22° W. through the Dry Creek Damsite). It extends from about 7 miles south of the Yuba River, where it is apparently truncated by the N. 30° W. trending Prairie Creek lineament, to about 16 miles north of the river where it projects into the Cleveland Hill fault.

14. Conclusions.

a. No evidence of ground cracks or surface faulting associated with the 1975 Oroville earthquake was found within the proposed Marysville project area.

b. There was no evidence found in exploration trenches of Quaternary or any faulting younger than bedrock structures along the Swain Ravine lineament in the Parks Bar-Dry Creek area.

c. Faulting which is younger than the bedrock fault structures reportedly has occurred along the Swain Ravine lineament about 11 miles northwest of Dry Creek Damsite (about 13 miles northwest of the Yuba River) in the Bureau of Reclamation's "Orange Avenue" trenches near Bangor.

d. About 8.5 miles south of the Yuba River, very small Quaternary displacement was reported in the Bureau of Reclamation's "Spenceville" trenches on the Prairie Creek lineament. Details and conclusions from the Bureau trenches are not available at this time.

e. Recent surface faulting occurred on the Cleveland Hill fault about 14 miles northwest of Dry Creek Damsite. The fault is a pre-existing (probably Jurassic) bedrock fault showing evidence of at least three episodes of small Quaternary displacements and was the source of the 1975 earthquake.

f. It is evident that several periods of faulting have affected the region. The earliest faults are the result of uplift during the Nevadan Orogeny and later batholithic intrusions during late Jurassic and Cretaceous time. The latest faulting and earthquakes are probably related to either uplift of the Sierran block beginning in Tertiary time, which would produce normal faulting along old zones of weakness, or regional readjustments due to stress buildups between the San Andreas transcurrent and the Basin and Range extensional tectonic regimes.

g. Two of the three major lineaments, the Swain Ravine and Prairie Creek lineaments, traverse the Marysville project area and are significant to it. The Swain Ravine lineament crosses the Yuba River about 2,500 feet downstream from the Parks Bar site and cuts through Dry Creek Damsite along the creek channel. The Prairie Creek lineament cuts through the area upstream from the Afterbay Damsite. Its location is about 500 feet upstream from the right abutment and about 2,000 feet upstream from the left abutment.

h. Mapping and trenching data indicates that the major lineaments consist of similar geologic features. The Swain Ravine lineament, which was concentrated on during this study, is a long linear topographic feature reflecting a relatively narrow, complex fault and shear zone. Most of the individual fault and shear structures observed at various places along the lineaments appear to be too small to account for the prominence and extent of the lineaments unless they are only part of the complex zone of these structures.

i. Even though the major lineaments appear to be old complex fault and shear zones that are probably associated with the overall Foothill Fault System, they were not found to be active in the project area. Recent movement (1975) on the Cleveland Hill fault to the north probably was restricted to a curving fault segment of limited extent in a complex zone of branching and interlacing fault segments as described in paragraph "n" following.

j. There is no evidence that sympathetic movement occurred on the Swain Ravine lineament as a result of the 1975 Oroville earthquake.

k. The sense of movement on the bedrock faults observed by others in trenches along the Swain Ravine and other lineaments was reported to be normal. Six of the seven fault structures exposed in Corps of Engineers Trenches 4F-1 to 4F-5 dip eastward, and only one dips westward similar to the Cleveland Hill fault. Faults in the Bureau's Orange Avenue trenches dip both westward and eastward, but the fault in their Spenceville trenches dips southwestward.

l. The northwest trend of the Prairie Creek lineament results in its cutting across the entire structural grain of the regional shear

zone and probably represents another through-going, complex bedrock structure similar to the Swain Ravine lineament only it is longer and larger. It coincides in part with the western boundary of the regional shear zone north of the Yuba River, crosses the river upstream of the Afterbay Damsite and has good continuity to the vicinity of Wellman Creek, continues southeastward through Austin Ravine and the mile-long jog in Bear Creek and then follows along the eastern boundary of the regional shear zone to the Rocklin Pluton. Because it cuts across the shear zone and possibly truncates the Swain Ravine lineament, it may be more recent than either feature.

m. Reconnaissance geologic mapping indicates that the location of the regional shear zone shown on the Geologic Map of California (1:250,000 scale) could be extended northward to include the Cleveland Hill fault area. Also, it could be extended eastward in the vicinity of Bangor to Pagnes Peak, and about a mile westward, at the Yuba River, it includes the area surrounding the Afterbay Damsite. Most of the eastern boundary appears to coincide well with the location on the state geologic map.

n. According to Corps of Engineers definition, a "capable fault" is one that is considered to have potential for generating an earthquake and exhibits unfavorable characteristics in one or more of the three categories discussed below.

(1) Movement within the last 35,000 years. In this study there was no evidence found of any movement at or near the ground surface in the project area within the last 35,000 years or in Quaternary time. The closest Quaternary faulting apparently occurred about 11 miles (Orange Avenue trenches) and 13.5 miles (Cleveland Hill fault) northwest from Dry Creek Damsite and about 8.5 miles southeast of Parks Bar Damsite (Spenceville trenches).

(2) Macro-seismicity records (3.5 magnitude or greater). Only one recorded earthquake prior to the 1975 Oroville earthquake has originated in the Northwestern Sierra foothills. That event was centered about 50 miles north of the Parks Bar area and occurred in 1940. There is no evidence to link it or its source fault to any fault known to be in the Parks Bar area.

(3) Structural relationship to a capable fault. About 16 miles north of the Yuba River, the Swain Ravine lineament apparently connects to the southeast end of the Cleveland Hill fault, which was active in the 1975 Oroville earthquake; and about seven miles south of the river, it is truncated or crossed by the Prairie Creek lineament, which was reported by the USBR to exhibit possible small Quaternary displacement in their Spenceville trenches. Therefore, the Swain Ravine lineament

would be considered a capable fault according to Corps of Engineers criteria because of its direct structural relationship to at least one active fault.

o. This study, as well as studies made by other agencies, indicates that the major linear features do not form single, long continuous fault structures but rather are complex zones with numerous short segments. The Swain Ravine lineament, which can be traced for about 23 miles and cuts through the project area, is a complex structure composed of numerous straight and curving, branching and interlacing faults, zones of sheared and foliated rock, zones of altered rock and intrusive dikes. The segmental character of the Swain Ravine lineament and all of the fault system in this area leads to the conclusion that any activity generated by the Foothill Fault System will produce small, not large magnitude earthquakes.

p. Historic records and observed displacements of Pleistocene age or younger show that the frequency of activity and earthquake magnitudes are greater north of Oroville than to the south on the Foothill Fault System. Displacements found in post-bedrock soil layers shows a pattern of becoming smaller from the north (Oroville area) at least as far south as the Rocklin Pluton.

q. Historical data, seismicity patterns, trench exploration of the major lineaments and general relationships of fault length and displacement lead to the conclusion that any displacement beneath the Dry Creek site would be very small (measured in inches) if the Swain Ravine lineament actually becomes active and generates seismic activity or undergoes sympathetic movement from activity or nearby structures. Potential for displacement is not known to exist at any of the other sites.

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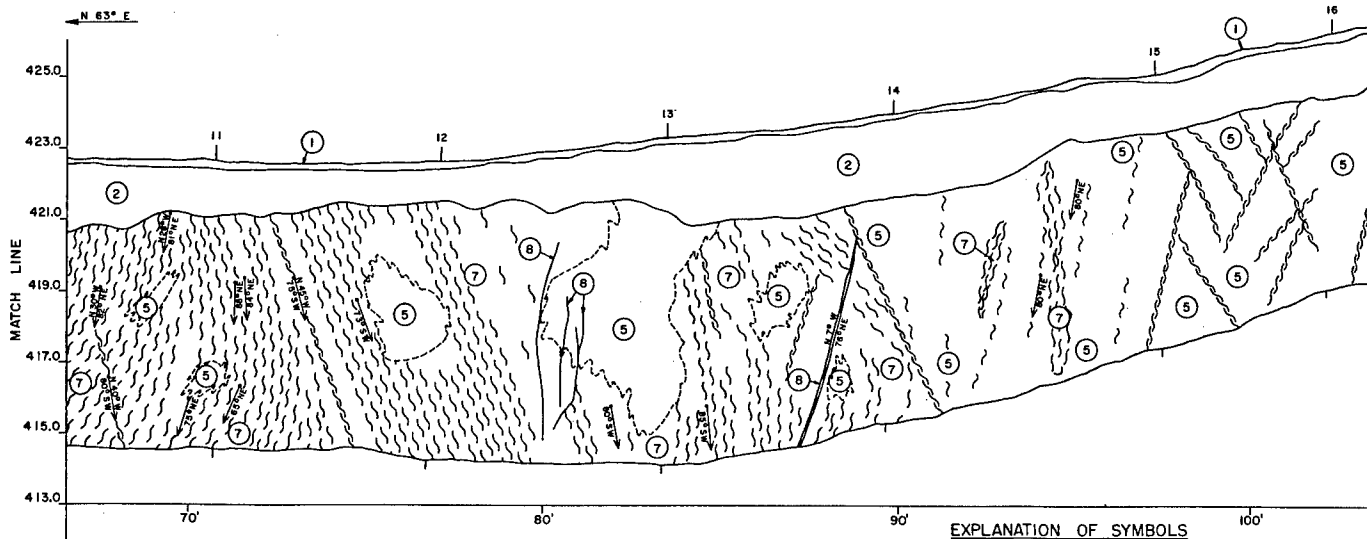
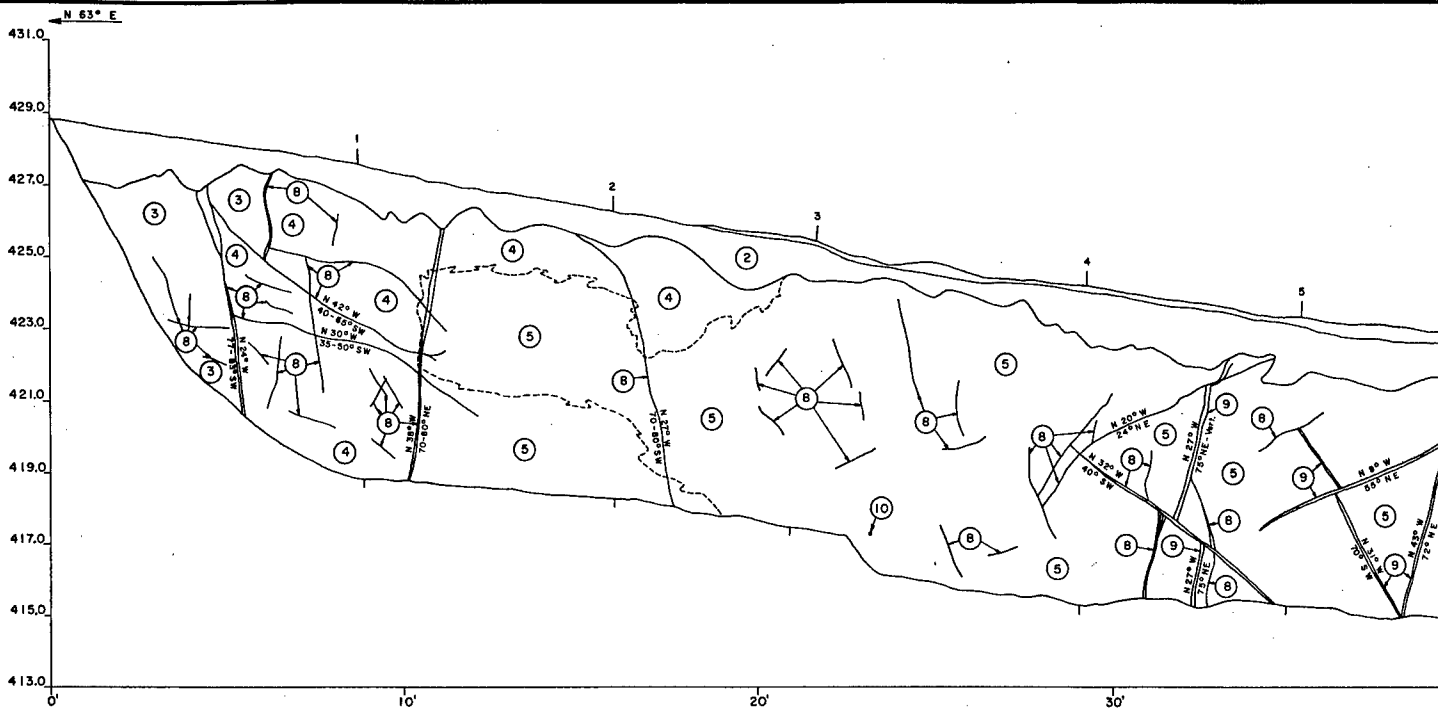
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EXPLANATION OF SYMBOLS

- OVERBURDEN**
- (1) COLLUVIUM I (Organic soil), Gravelly Silty Sand, light brown, mostly fine sand, some medium and coarse, large percent silt, scattered subangular to subrounded metavolcanic (agglomerate) rock fragments to 3" maximum diameter, loose and dry, contains abundant organic material, mostly grass roots, 0.1 to 1.6 feet thick, non-plastic fines (F.C.).
 - (2) COLLUVIUM II (Slopewash), Gravelly Sandy Silt, brown to light reddish brown, contains scattered to abundant subangular to subrounded fragments of metavolcanic (agglomerate) rock from gravel size to 5 or 6 inch diameter cobbles, soft and dry, varies from 0.3 to 2.5 feet thick, non-plastic to slightly cohesive fines. A concentration of rock fragments occurs between 50 and 95 feet along the trench.

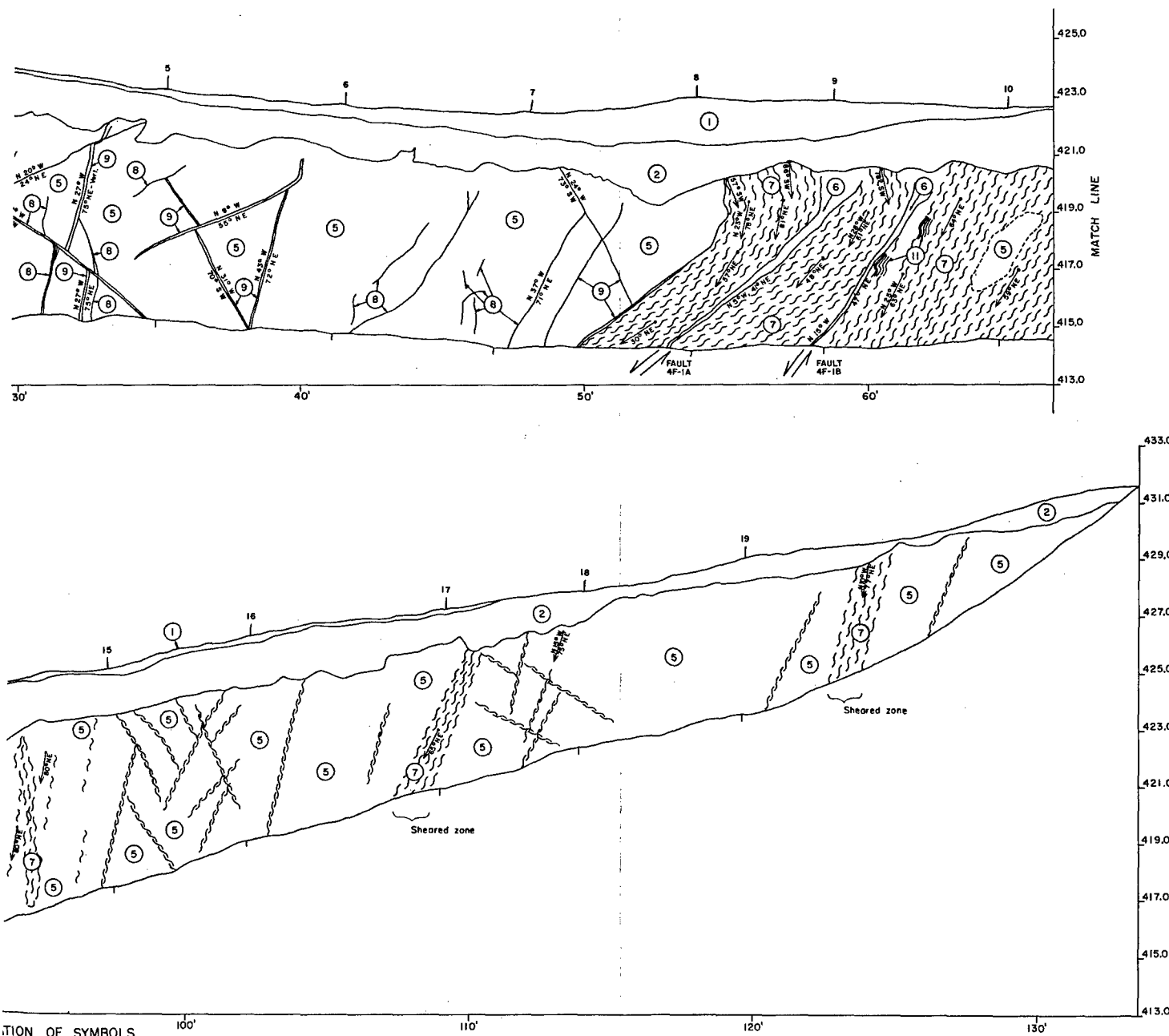
- BEDROCK**
- (3) METAVOLCANICS (Agglomerate), brownish green, spanitic matrix or groundmass with scattered 0.1 to 0.4 foot subangular to subrounded spherically shaped fragments or pyroclasts. Fragments are porphyritic with feldspar phenocrysts or amygdaloidal with 1/10-1/8 inch calcite or quartz vesicle fillings, the rock is moderately soft to moderately hard, massive, blocky non-foliated appearance, moderately weathered, partly spheroidally weathered, moderately to highly jointed with 3-5 inch spacing. Some joints are altered-see description (8). Parts of the upper surface are highly gradational from highly weathered rock to residual soil.
 - (4) SAME AS (3), moderately to highly weathered to light brownish green, soft to moderately soft, highly jointed with 1/2-1 1/2 inch spacing, altered joints to 0.2 foot thick - see description (8).
 - (5) SAME AS (3), moderately to highly weathered to greenish tan, soft, highly jointed with 1/2-2 1/2 inch spacing, scattered altered joints - see descriptions (8) and (9), rock slightly foliated between 90 and 98 feet along the trench.
 - (6) FAULTY GOUGE, gray to light grayish green, some bluish green and white streaks, consists of clay with small rock fragments, firm to stiff and damp, few plant roots, gouge varies from 0.1 to 1.4 feet wide and grades indistinctly into residual soil at the top, the clay is moderately to highly plastic.

- (7) SAME AS (3), partly altered to white with yellowish tan streaks, highly foliated and sheared, most or has been destroyed, varies from soft to moderate.
- (8) ALTERED JOINT, light salmon pink with some white, varies from a 0.1 inch to 0.2 foot wide-zone of a adjacent to each side of the joint. Some joint p coated with a hard, siliceous, light grayish green material, probably epidote-quartz and calcite.
- (9) SAME AS (8), light yellowish brown and white, var 0.1 inch to 0.1 foot wide-zone of mostly clay.
- (10) Bluish green scaly coatings found on plant roots-soluble copper minerals.
- (11) Drag folding shown diagrammatically in sheared rock Fault 4F-1B indicates normal movement.

NOTES:

Numbers 1 to 16 along top of trench indicate the center 19 sets of shoring used for trench wall support.
Trench bottom was not excavated to refusal by backhoe (

ENGINEERING PAYS



NOTES

SAME AS (3), partly altered to white with yellowish brown and tan streaks, highly foliated and sheared, most original texture has been destroyed, varies from soft to moderately soft.

ALTERED JOINT, light salmon pink with some white streaks, varies from a 0.1 inch to 0.2 foot-wide-zone of altered rock adjacent to each side of the joint. Some joint planes are coated with a hard, siliceous, light grayish green, laminated material, probably epidote-quartz and calcite.

SAME AS (8), light yellowish brown and white, varies from a 0.1 inch to 0.1 foot-wide-zone of mostly clay.

Bluish green scaly coatings found on plant roots-possibly soluble copper minerals.

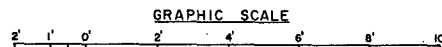
Drag folding shown diagrammatically in sheared rock beneath Fault 4F-1B indicates normal movement.

NOTES

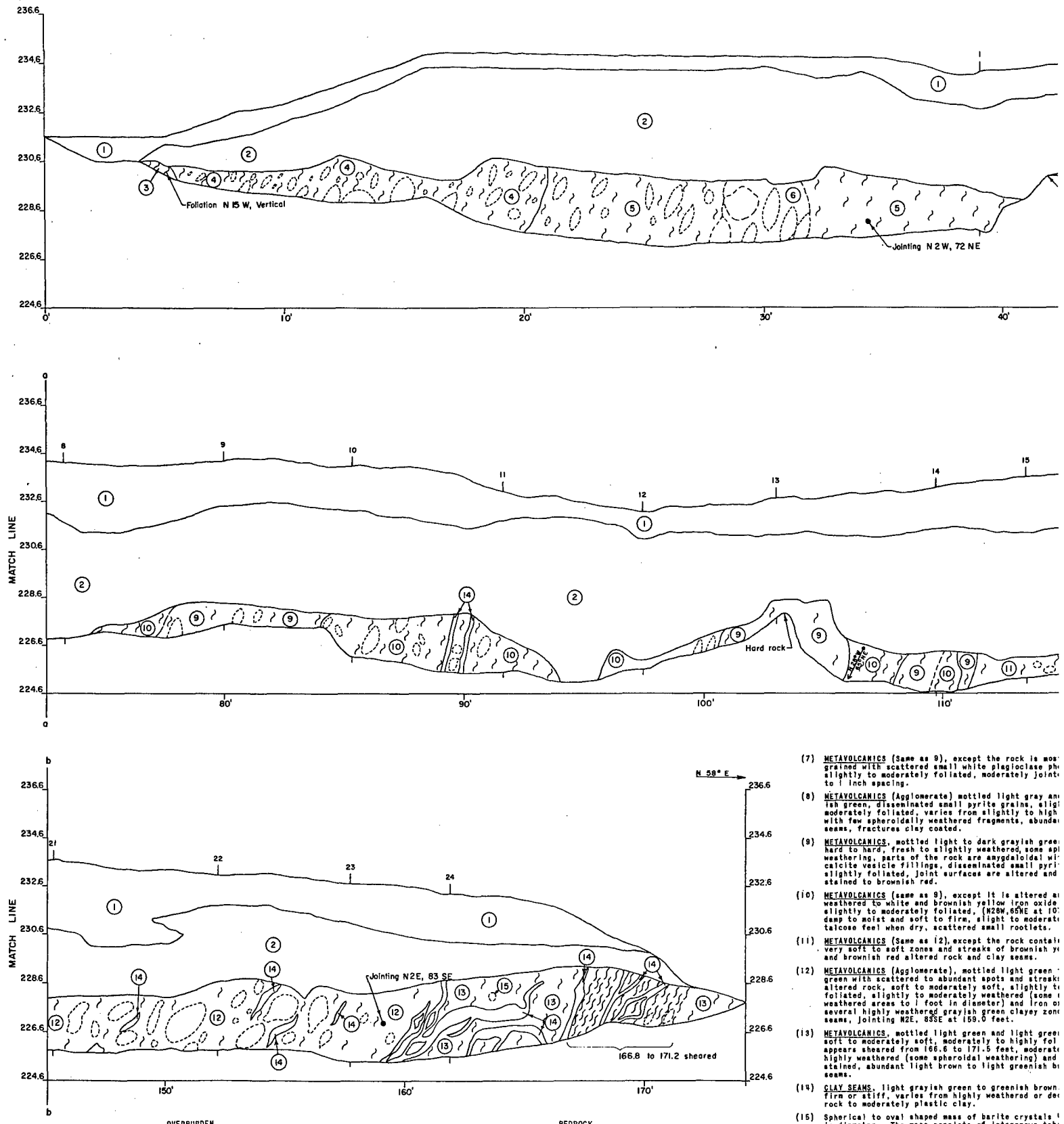
* 1 to 19 along top of trench indicate the center location of is of shoring used for trench wall support.

1 bottom was not excavated to refusal by backhoe (Case 580 B).

- Geologic contact.
- - - Approximate geologic contact.
- ~~~~~ Shear zone.
- ~~~~~ Shear with strike and dip.
- ~~~~~ Shear with apparent dip.
- ~~~~~ Strike and dip of foliation.
- ~~~~~ Apparent dip of foliation.



REVISION	DATE	DESCRIPTION	BY	BY
<p align="center">DEPARTMENT OF THE ARMY SACRAMENTO DISTRICT, CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA</p>				
<p>DESIGNED BY: DRAWN BY: CHECKED BY: PREPARED BY: SUBMITTED BY:</p>		<p align="center">MARYSVILLE LAKE PROJECT PARKS BAR ALTERNATE FAULT EVALUATION STUDY LOG OF TRENCH 4F-1 SOUTH WALL</p>		
<p>APPROVAL RECOMMENDED:</p>		<p>APPROVED: _____ DATE: _____</p>		
<p>PREPARED UNDER THE DIRECTION OF</p>		<p>SCALE: AS SHOWN SPEC. NO.</p>		
<p>DONALD M. O'SHEI COL., CORPS OF ENGINEERS, U. S. A.</p>		<p>FILE NO. YU-4-20-39 SHEETS 39/6 to 39/11 SHEET NO. 39/6</p>		



- (1) **ALLUVIUM I** (Flood Plain Deposit), Gravelly Sandy Silt, light brown, large percent fine sand, some medium to coarse, scattered subangular to rounded gravel to 3 inches in diameter, contains numerous tree and bush roots, loose to soft and dry to slightly damp, non-cohesive.
- (2) **ALLUVIUM II** (Streambed Deposit), Sand, Sandy Gravel, Gravelly Sand, light brown and gray, discontinuous lenticular sand and gravel with scattered basal gravels and a few cobbles (subangular to rounded) to 5 or 6 inches in diameter, mostly clean material with a small percent silt, loose and dry except at water level, few zones or streaks of sand coated with a dull black coating, probably manganese oxide.

- (3) **METAVOLCANICS** (Mineralized or altered tuff), light brownish green to greenish brown, moderately soft to hard, moderately foliated (N 5 W, vertical), scattered brown weathered phenocrysts, possibly siderite with augen structure, some slicken-sided internal planes.
- (4) **METAVOLCANICS** (Same as 3), except slightly to moderately weathered to light brown and yellowish brown, soft to moderately soft and crumbly, joints coated with grayish green clay.
- (5) **METAVOLCANICS** (Same as 3), except the rock is mostly altered and highly weathered to grayish green clay, stained yellowish brown by iron oxide, soft to very soft, jointing N 2 W, 72 NE at 34.5 feet parallel to foliation.
- (6) **METAVOLCANICS** (Same as 3), except the rock is less weathered than adjacent rock and there are abundant large spheroidally weathered fragments.

- (7) **METAVOLCANICS** (Same as 3), except the rock is more grained with scattered small white plagioclase phenocrysts, slightly to moderately foliated, moderately jointed to 1 inch spacing.
- (8) **METAVOLCANICS** (Agglomerate), mottled light green and light brown, disseminated small pyrite grains, slightly to moderately foliated, varies from slightly to high with few spheroidally weathered fragments, abundant seams, fractures clay coated.
- (9) **METAVOLCANICS**, mottled light to dark grayish green, hard to hard, fresh to slightly weathered, some spheroidally weathered, parts of the rock are amygdaloidal with calcite vesicle fillings, disseminated small pyrite, slightly foliated, joint surfaces are altered and stained to brownish red.
- (10) **METAVOLCANICS** (Same as 9), except it is altered to white and brownish yellow iron oxide, slightly to moderately foliated, (N 2 W, 65 NE at 10' damp to moist and soft to firm, slight to moderate talcoses feel when dry, scattered small rootlets.
- (11) **METAVOLCANICS** (Same as 12), except the rock contains very soft to soft zones and streaks of brownish yellow and brownish red altered rock and clay seams.
- (12) **METAVOLCANICS** (Agglomerate), mottled light green and light brown with scattered to abundant spots and streaks of altered rock, soft to moderately soft, slightly to foliated, slightly to moderately weathered (some highly weathered areas to 1 foot in diameter) and iron or several highly weathered grayish green clayey zones, jointing N 2 E, 83 SE at 159.0 feet.
- (13) **METAVOLCANICS**, mottled light green and light green, soft to moderately soft, moderately to highly foliated, appears sheared from 166.8 to 171.5 feet, moderate to highly weathered (some spheroidally weathered) and stained, abundant light brown to light greenish brown seams.
- (14) **CLAY SEAMS**, light grayish green to greenish brown, firm or stiff, varies from highly weathered or dark rock to moderately plastic clay.
- (15) **Spherical to oval shaped mass of barite crystals** 1/2 inch in diameter. The mass consists of intergrown tabular opaque to semi-transparent crystals. The surface oxide stained and is enclosed in light greenish gray.

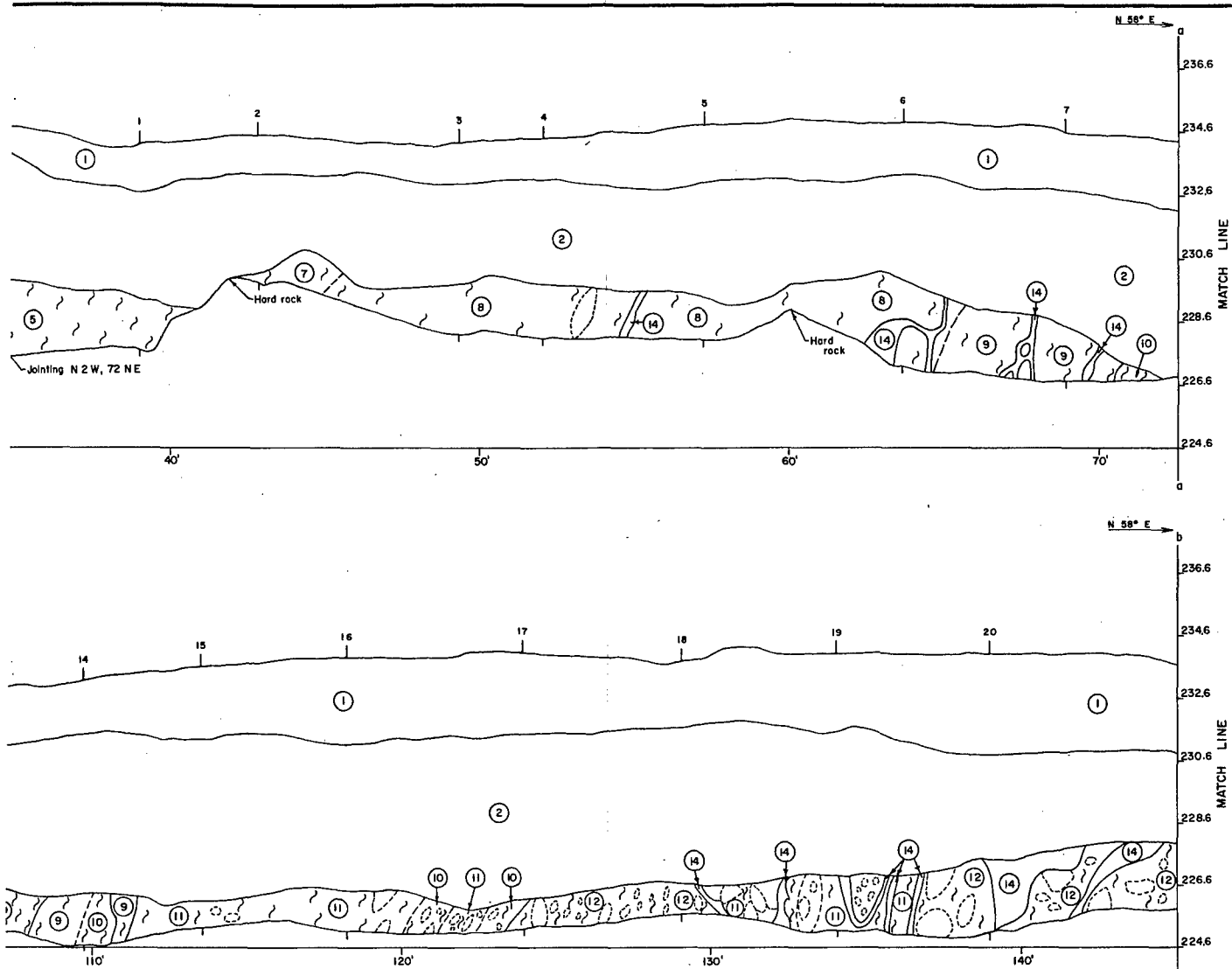
NOTES

Numbers 1 to 24 along top of trench indicate the center, 24 sets of shoring used for trench wall support.

Trench bottom excavated to refusal with a Case 580 B bar.

INEERING PAYS

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EXPLANATION OF SYMBOLS

CS (Same as 9), except the rock is mostly fine grained, with scattered small white plagioclase phenocrysts, moderately foliated, moderately jointed with 1/2 spacing.

CS (Agglomerate) mottled light gray and dark gray, disseminated small pyrite grains, slightly to moderately foliated, varies from slightly to highly weathered spheroidally weathered fragments, abundant clay, striae clay coated.

CS, mottled light to dark grayish green, moderately to fresh to slightly weathered, some spheroidal, parts of the rock are amygdaloidal with small silt fillings, disseminated small pyrite grains, foliated, joint surfaces are altered and iron oxide brownish red.

CS (same as 9), except it is altered and highly to white and brownish yellow iron oxide stained clay, moderately foliated, (K20W, 65NE at 107.0 feet) soft and soft to firm, slight to moderate plasticity, when dry, scattered small rootlets.

CS (Same as 12), except the rock contains abundant to soft zones and streaks of brownish yellow, white to red altered rock and clay seams.

CS (Agglomerate), mottled light green to grayish scattered to abundant spots and streaks of white clay, soft to moderately soft, slightly to moderately slightly to moderately weathered (some spheroidally areas to 1 foot in diameter) and iron oxide stained, highly weathered grayish green clayey zones and clay jointing N2E, 85SE at 159.0 feet.

CS, mottled light green and light greenish brown, moderately soft, moderately to highly foliated, altered from 166.6 to 171.5 feet, moderately to altered (some spheroidal weathering) and iron oxide abundant light brown to light greenish brown clay.

light grayish green to greenish brown, soft to stiff, varies from highly weathered or decomposed to moderately plastic clay.

to oval shaped mass of barite crystals 1/4 to 5 inches in size. The mass consists of intergrown tabular, white semi-translucent crystals. The surface is iron red and is enclosed in light greenish gray clay.

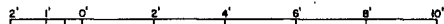
NOTES

along top of trench indicate the center location of auger used for trench wall support.

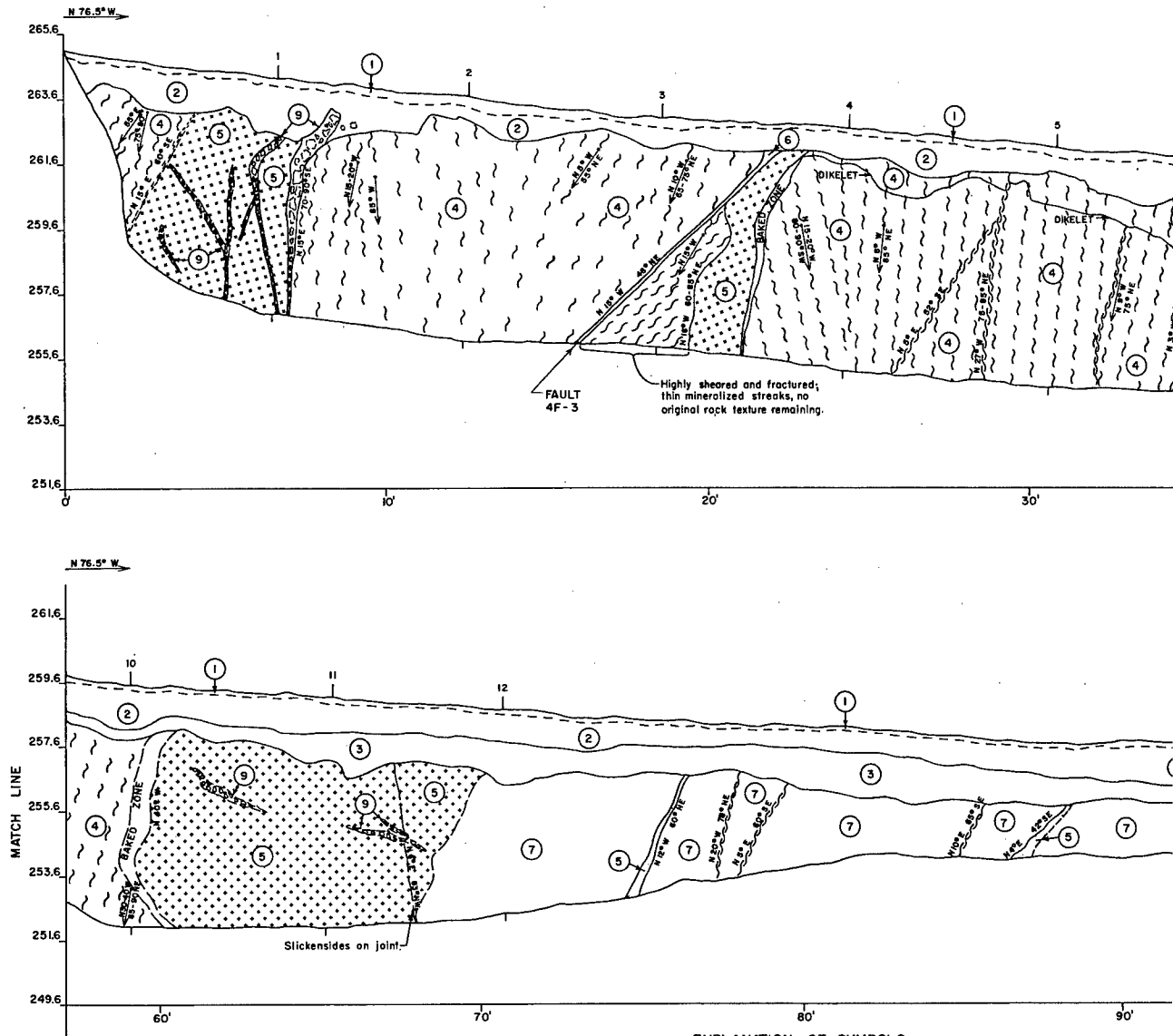
cavated to refusal with a Case 580 B backhoe.

- Geologic contact.
- - - Approximate geologic contact.
- ~ ~ ~ Shear zone.
- ~ ~ ~ Foliation.
- Spheroidally weathered structure.

GRAPHIC SCALE



DESIGNED BY: D. W. Poigs	CHECKED BY: R. J. Anderson	APPROVED BY: J. L. Grewarth, A. P. Buer	DATE:
<p>DEPARTMENT OF THE ARMY SACRAMENTO DISTRICT, CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA</p> <p>MARYSVILLE LAKE PROJECT PARKS BAR ALTERNATE FAULT EVALUATION STUDY LOG OF TRENCH 4F-2 SOUTH WALL</p>			
APPROVAL RECOMMENDED:		APPROVED:	
CHIEF OF ENGINEERING		CHIEF OF ENGINEERING	
PREPARED UNDER THE DIRECTION OF DONALD M. O'SHEI COL., CORPS OF ENGINEERS, U. S. A.		SCALE: AS SHOWN FILE NO. YU-4-20-39 SHEETS 39/6 to 39/11 SHEET NO. 39/7	



EXPLANATION OF SYMBOLS

OVERBURDEN

- (1) COLLUVIUM I (Organic soil) Sandy Silt, tan to brown, sand fine to medium grained, scattered subangular to subrounded meta-volcanic (agglomerate) rock fragments to 1 1/2" in diameter, loose and dry, abundant organic material—mostly grass roots, varies from 0.1 to 0.4 foot in thickness, non-plastic fines (F.C.).
- (2) COLLUVIUM II (Slopewash) Sandy Silt, light reddish brown, 10-20% sand, mostly fine grained, scattered rounded to subangular gravel to 1 1/2" diameter and a few subangular meta-volcanic agglomerate rock fragments to 1" diameter, loose to firm and dry, varies from 0.3 to 1.6 feet thick, moderately cohesive fines (F.C.).
- (3) RESIDUAL SOIL Sandy Clay, light brown to light reddish brown, 15-20% angular sand-size rock fragments mostly very fine to medium with some coarse grained and scattered 3/8 inch pea gravel-size fragments, firm to stiff and dry to damp, slightly to moderately plastic clay, no original rock texture preserved, exhibits prismatic cracks (jointing) upon desiccation. The residual soil occurs from 55.0 to 104.2 feet and varies in thickness from 0.1 foot to 1.5 feet (F.C.).

BEDROCK

- (4) METAVOLCANICS (Agglomerate), brownish yellow and yellowish brown with light tan to white streaks and fragments, soft to moderately hard, moderately to highly weathered and decomposed between 0 and 60 feet, highly foliated and locally sheared, contains abundant altered rock, aphanitic groundmass with abundant angular to subrounded amygdaloidal fragments or pyroclasts from 1/4 inch to 4 inch in diameter, some are undeformed but most are elongated parallel to the foliation, highly jointed with spacing from 1/2 inch to 3 inch apart, joint surfaces are iron oxide stained.

- (5) DIKE, light brownish tan to light greenish brown, aphanitic groundmass with scattered fine grained phenocrysts, massive—no foliation or shears, not altered, abundant irregular 1/2 inch to 4 inch wide quartz seams common to the larger dikes, thin dikelets extend from main dikes at 21.0 and 36.0 feet, contacts between dikes and adjacent rock are generally irregular and some exhibit baked zones or chilled margins, dikes generally dip steeply eastward, the rock is highly jointed with spacing from 1/2" to 2" apart, joints stained brownish red by iron oxide.
- (6) FAULT GOUGE, light greenish gray, consists of clay and small rock fragments, firm to stiff and damp, varies from 0.1 foot thick at the trench floor to 0.3 foot thick at the contact with the slopewash, the clay is moderately to highly plastic.
- (7) METAVOLCANICS (Agglomerate), brownish green, moderately soft to moderately hard, aphanitic groundmass with abundant angular to subrounded fragments (pyroclasts) from 1/2 inch to about 1 inch in diameter, rock is massive—no foliation or shears, not altered, moderately to highly weathered, highly jointed with spacing from 1/2 inch to 2 inches apart. Joint surfaces are iron oxide stained.
- (8) METAVOLCANICS (Same as 7), has the appearance of an amygdaloidal basalt due to the abundance of large (4-5 inch diameter ±) amygdaloidal basalt pyroclasts with numerous silica and calcite filled amygdulites to about 1/8 inch diameter and numerous vesicles where they have weathered out.
- (9) QUARTZ VEINS, white, opaque igneous quartz veins associated with intrusion of the larger dikes, they are highly fractured into angular fragments of various sizes and are coated and enclosed by highly plastic brownish red clay mixed with weathered fragments of the adjacent rock.

NOTES:

Numbers 1 to 12 along top of trench indicate the center 12 sets of shoring used for trench wall support.

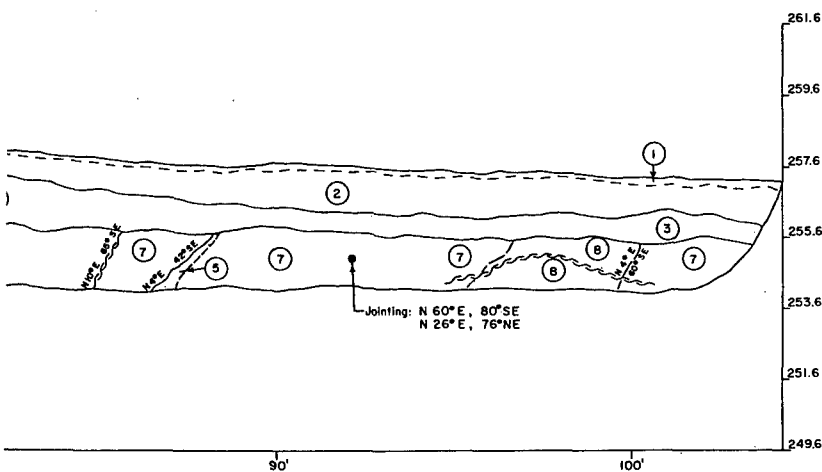
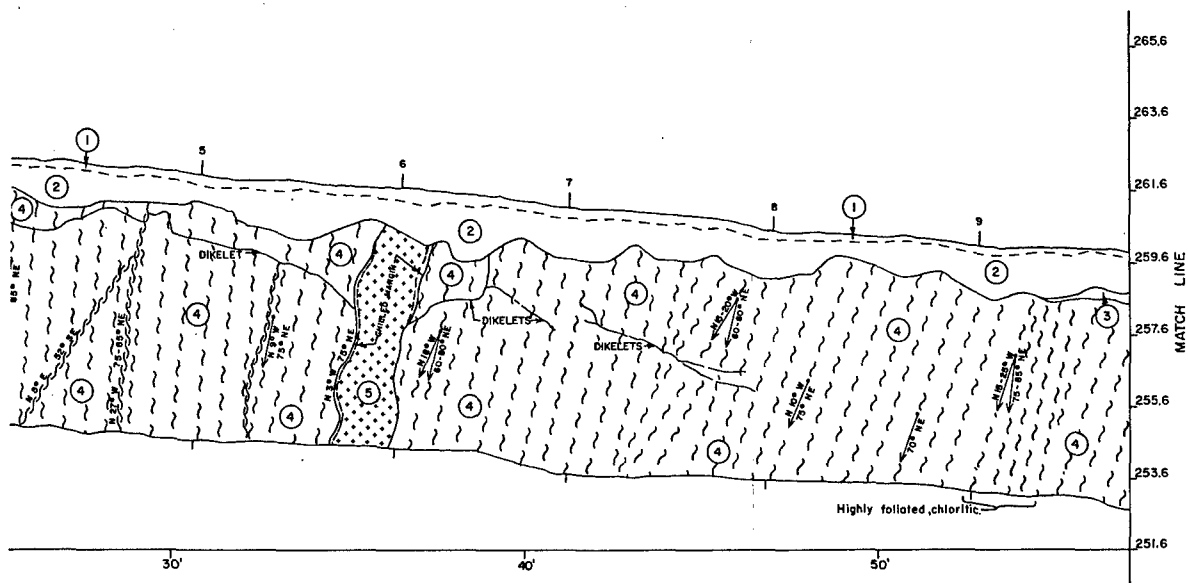
Trench bottom was not excavated to refusal by backhoe.

Baked zone refers to a siliceous, partially laminated, boundary between the intrusive dike and the adjacent wall (agglomerate) which may be a result of thermal alteration by the intruding dike.

Chilled margin refers to a thin zone within the dike but is finer grained and appears more siliceous than rock in center due probably to the chilling effect or cooling of the wall rock.

Dikelet refers to a small offshoot or branch from a dike it is attached.

ENGINEERING PAYS



OLS

NOTES:

i to i2 along top of trench indicate the center location of of shoring used for trench wall support.

ottom was not excavated to refusal by backhoe (Case 580 B).

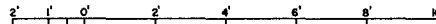
is refers to a siliceous, partially laminated, non-distinct between the intrusive dike and the adjacent wall rock rate) which may be a result of thermal alteration produced intruding dike.

Margin refers to a thin zone within the dike boundaries that grained and appears more siliceous than rock toward the vo probably to the chilling effect or cooling by contact wall rock.

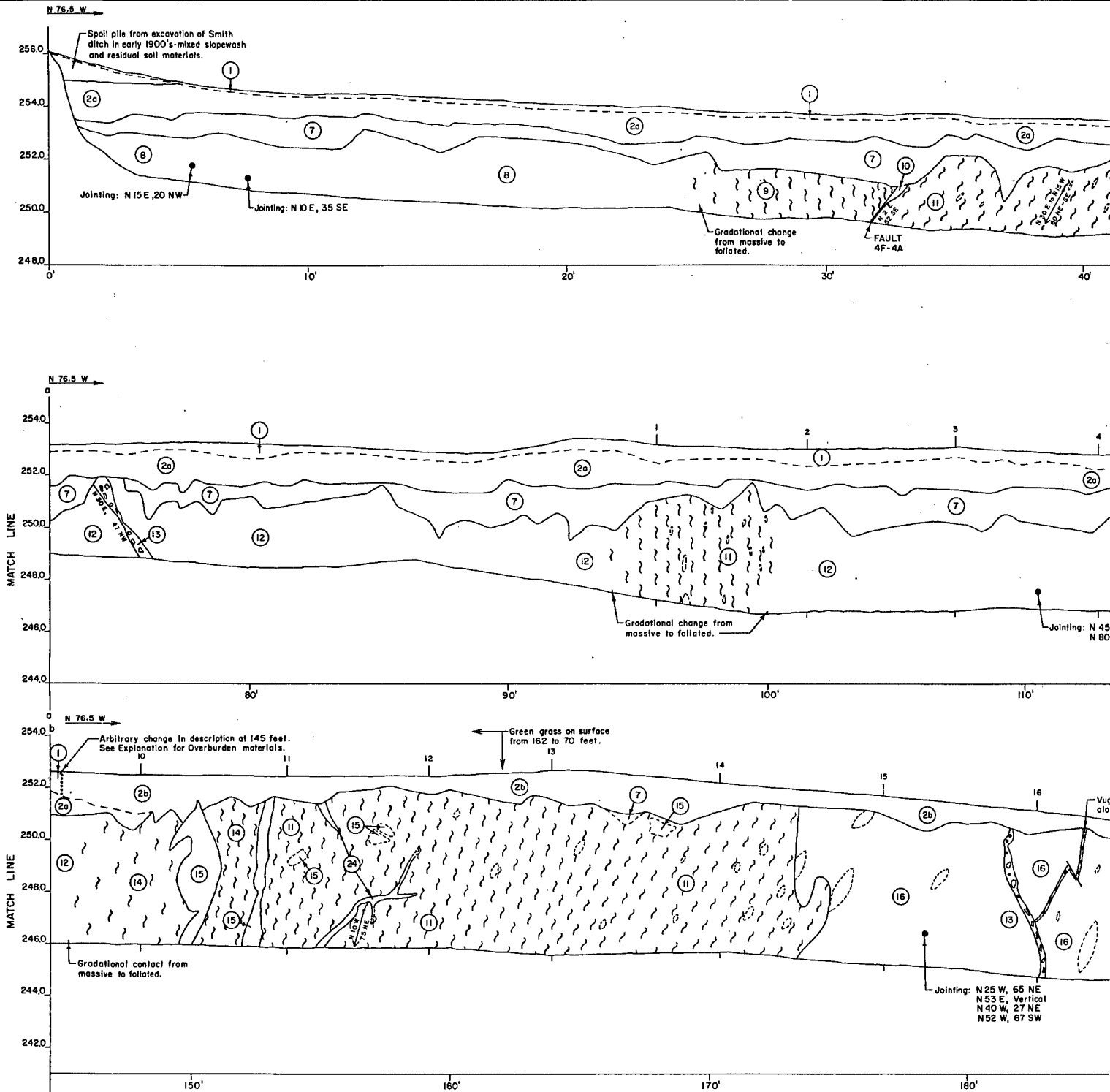
refers to a small offshoot or branch from a dike to which tached.

- Geologic contact.
- - - - - Approximate geologic contact.
- ~~~~~ Shear zone.
- N 5° E 82° SE Shear with strike and dip.
- N 4° E 42° SE Joint with strike and dip.
- ~~~~~ Foliation.
- N 10° W 75° NE Strike and dip of foliation.
- ~~~~~ Apparent dip of foliation.

GRAPHIC SCALE



REVISION	DATE	DESCRIPTION	BY	BY
<p align="center">DEPARTMENT OF THE ARMY SACRAMENTO DISTRICT, CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA</p>				
<p>DESIGNED BY: DRAWN BY: D. W. Poige CHECKED BY: R. J. Anderson PREPARED BY: R. L. Tread J. A. Masto, A. B. Price SUBMITTED: P. J. H. Allen CIVIL ENGINEERING SECTION</p>		<p align="center">MARYSVILLE LAKE PROJECT PARKS BAR ALTERNATE FAULT EVALUATION STUDY LOG OF TRENCH 4F-3 SOUTH WALL</p>		
<p>APPROVAL RECOMMENDED: CHIEF OF ENGINEERS, DISTRICT PREPARED UNDER THE DIRECTION OF DONALD M. O'SHEI COL., CORPS OF ENGINEERS, U. S. A.</p>		<p>APPROVED: [Signature] DATE: _____ CHIEF OF ENGINEERS, DISTRICT</p>		
<p>SCALE: AS SHOWN FILE NO. YU-4-20-39 SHEETS 39/6 to 39/11</p>		<p>SPEC. NO. SHEET NO. 39/8</p>		



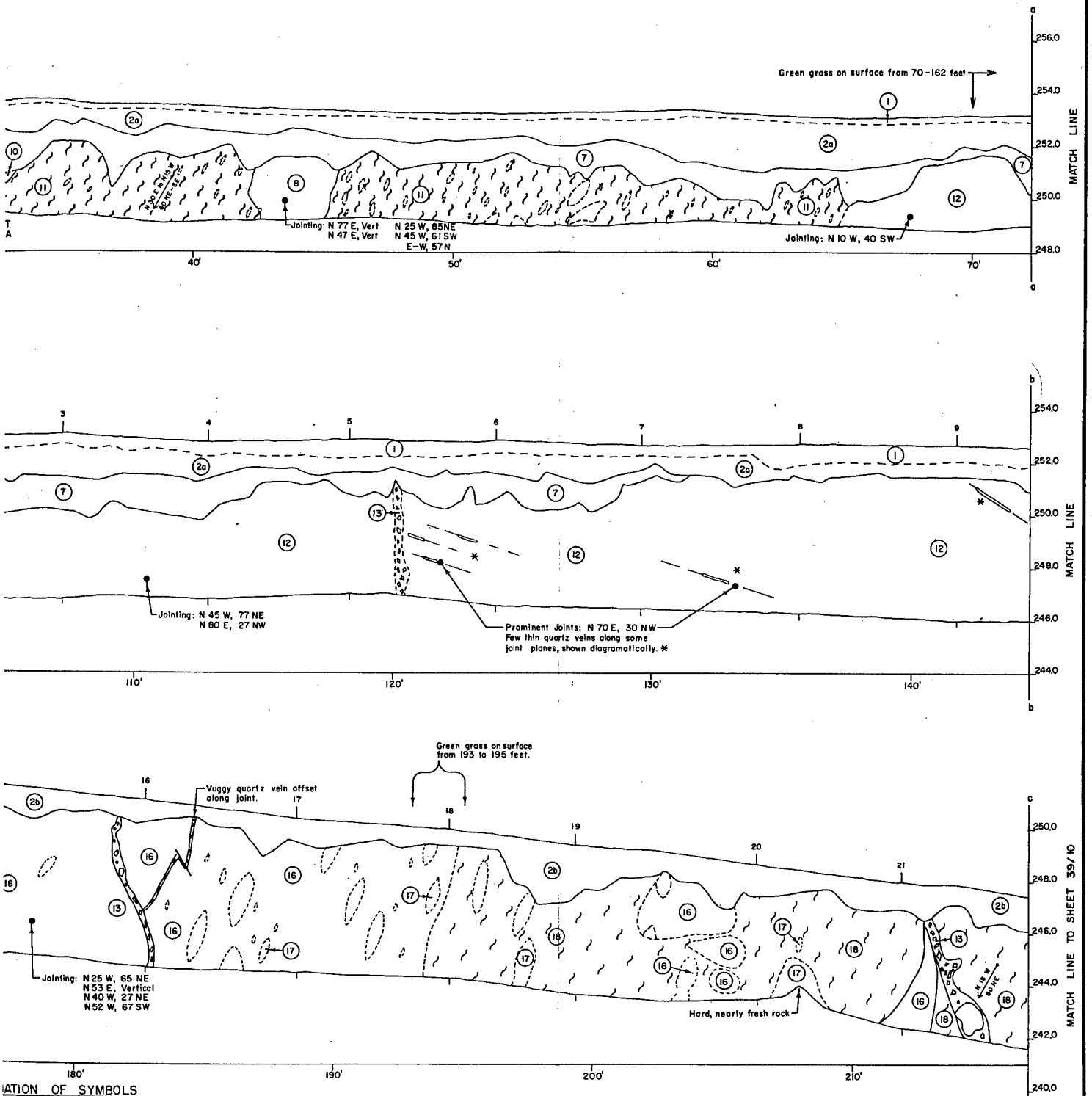
EXPLANATION OF SYMBOLS

- OVERBURDEN**
- (1) **COLLUVIUM I (Organic soil), Sandy SH.** brown to dark brown, large percent very fine sand, some medium and coarse sand, scattered sub-angular small gravel-size rock fragments, little clay, non-plastic fines, loose and dry. Organic soil is a separate unit from 0 to 145 feet only. From 145.0 to 349.6 feet, organic material is present throughout the various slopewash units described below (F.C.).
 - (2) **COLLUVIUM II SLOPEWASH.** This material is divided into 5 units based on differences in composition. Arbitrary vertical dotted contacts separate the units on the log. Individual units 2a to 2e are described below.
 - (2a) **GRAVELLY SANDY CLAY,** light reddish brown, large percent silt, and fine sand, some medium to coarse sand, scattered sub-angular to angular gravel-size weathered rock fragments from 1/4 to 3 inch diameter occur mostly near the base of the unit, slightly to moderately plastic fines, dry and loose to firm (F.C.).
 - (2b) **GRAVELLY SANDY SILT,** brown, small percent clay, contains scattered subangular to angular gravel and small cobble size rock fragments to 6 inches diameter, contains abundant tree roots and organic material, varies from 0.4 to 2.4 feet thick, damp and loose, cohesive, non-plastic fines, from 170 to 20 feet contains abundant fragments of dislodged and weathered near surface bedrock (F.C.).

- (2c) **GRAVELLY SANDY SILT,** brown to light reddish brown, essentially the same as unit 2b except there are no tree roots, very few scattered rounded gravels to 3 inches in diameter at the lower end of unit.
- (2d) **SANDY SILTY GRAVEL and GRAVELLY SANDY SILT,** brown to brownish gray, consists of a mixture of gravelly stream deposits and slopewash as above, large percent well rounded gravels and cobbles to 7 inches in diameter, sand mostly very fine to fine grained, some medium and coarse sand, dry and loose to firm, some surface areas disturbed by ranching operations.
- (2e) **GRAVELLY SANDY SILT,** brown to brownish gray, essentially the same as unit 2d with the addition of numerous tree roots and organic matter.
- (3) **COLLUVIUM III GRAVELLY SANDY CLAY,** light brown to brownish gray, contains a large percent silt, abundant subangular gravel-size rock fragments and rounded gravel, moderately to highly plastic fines, dry and firm, consists of slopewash derived from nearby materials. The last three feet at the west end contains abundant angular, weathered fragments of detached, near surface bedrock.

- (4) **COLLUVIUM IV SANDY CLAY,** brown, sand ranges moderately plastic clay, dry and firm to stiff, consists of fine grained stream alluvium, or a B soil from the underlying alluvium.
- (5) **ALLUVIUM I SANDY CLAY,** mottled light brown gravel particles are decomposed with vague plastic fines, dry and firm to stiff, numerous caliche streaks, consists of a highly weathered horizon developed from the underlying parent.
- (6) **ALLUVIUM II GRAVELLY SILTY SAND,** light brown fine to coarse and subangular to rounded, s to well rounded gravel and cobbles to 8 inc some silt and clay in matrix, dry and dense ment with caliche, highly weathered old a possibly Pleistocene age or older.
- (7) **RESIDUAL SOIL SANDY CLAY,** light reddish brown, consists of a clay-rich zone of deep bedrock, contains about 15% angular, fine t rock fragments, scattered small angular gra fragments, no original rock texture, dry to stiff, exhibits prismatic cracks (joints) u

ENGINEERING PAYS



EXPLANATION OF SYMBOLS

ALLUVIUM IV SANDY CLAY, brown, sand ranges from fine to coarse, moderately plastic clay, dry and firm to stiff, appears to consist of slopewash derived from nearby materials, could be deposit of fine grained stream alluvium, or a B soil horizon developed from the underlying alluvium.

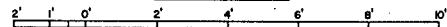
ALLUVIUM I SANDY CLAY, mottled light brown and tan, rounded gravel particles are decomposed with vague outlines, moderately plastic fines, dry and firm to stiff, numerous irregular siliceous streaks, consists of a highly weathered C₁ soil horizon developed from the underlying parent alluvium.

ALLUVIUM II GRAVELLY SILTY SAND, light brownish gray, sand is fine to coarse and subangular to rounded, scattered subangular well rounded gravel and cobbles to 8 inches in diameter, some silt and clay in matrix, dry and dense to slightly cemented with caliche, highly weathered old stream deposit, possibly Pleistocene age or older.

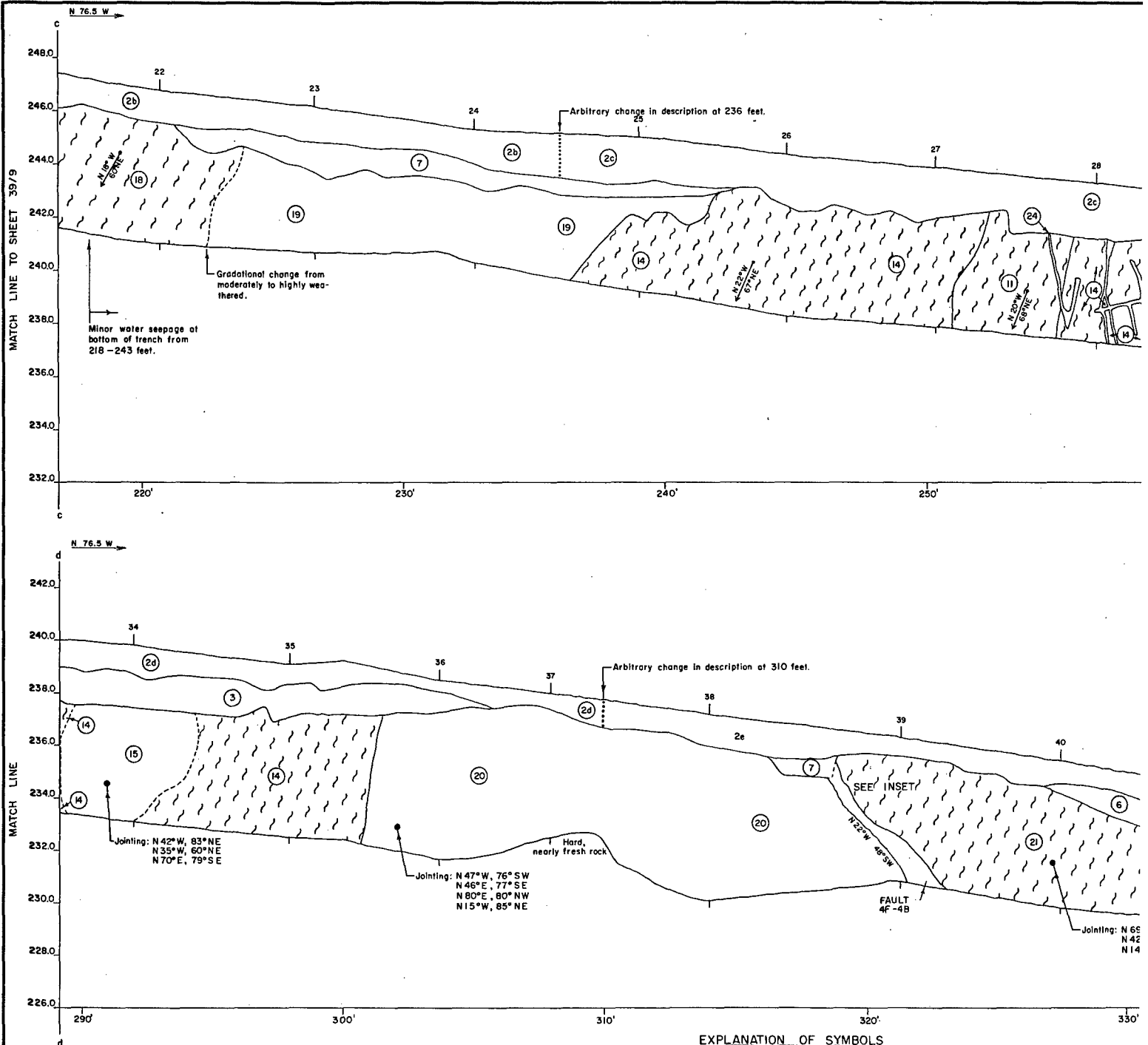
RESIDUAL SOIL SANDY CLAY, light reddish brown to light greenish brown, consists of a clay-rich zone of decomposed metavolcanic rock, contains about 15% angular, fine to medium sand-size rock fragments, scattered small angular gravel size rock fragments, no original rock texture, dry to damp and firm to stiff, exhibits prismatic cracks (joints) upon desiccation.

- Geologic contact.
- Approximate geologic contact.
- Foliation.
- Strike and dip of foliation.
- Spheroidally weathered structure.

GRAPHIC SCALE



REVISION	DATE	DESCRIPTION	BY	BY
DEPARTMENT OF THE ARMY SACRAMENTO DISTRICT, CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA				
MARYSVILLE LAKE PROJECT PARKS BAR ALTERNATE FAULT EVALUATION STUDY LOG OF TRENCH 4F-4 SOUTH WALL				
DESIGNED BY: DRAWN BY: CHECKED BY: PREPARED BY: SUBMITTED: CHIEF, GEOLOGY SECTION		APPROVED: _____ DATE: _____		
PREPARED UNDER THE DIRECTION OF DONALD M. O'SHEI COL., CORPS OF ENGINEERS, U.S.A.		SCALE: AS SHOWN FILE NO. YU-4-20-39 SHEETS 39/6 to 39/11 SHEET NO. 39/9		



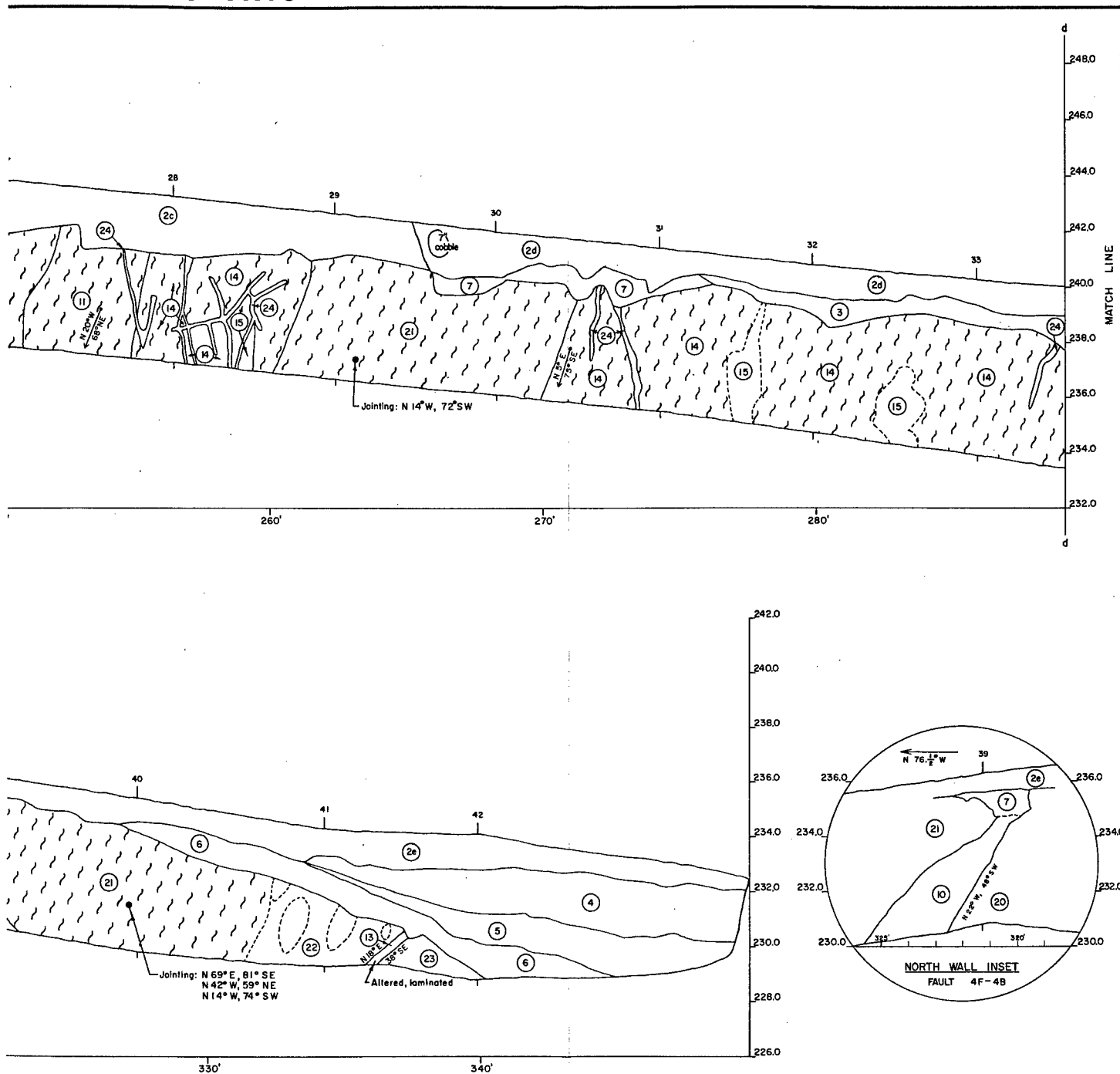
EXPLANATION OF SYMBOLS

- BEDROCK**
- (8) METAVOLCANICS (Tuff breccia), greenish gray, fine to medium grained white speckled groundmass with 1/4" to 1" angular to subangular fragments, moderately soft to moderately hard, highly jointed with average 1" spacing, joints have brownish yellow to white coating, rock moderately weathered.
 - (9) METAVOLCANICS (Same as 8) slightly to moderately foliated N.10°W., vertical to steeply eastward, foliation planes are shiny and possibly chloritized.
 - (10) FAULT, SOUVE, light greenish gray, consists of clay and small rock fragments, deep and firm to stiff, varies from 0.2 to 0.6 foot thick on fault 4F-4A and 0.5 to 2.2 feet thick on fault 4F-4B, the clay is moderately to highly plastic.
 - (11) METAVOLCANICS, brownish yellow and white, moderately foliated with lenticular white altered fragments which are massive and jointed, fragments contain weathered-out pyrite outlines, rock soft to moderately soft and moderately to highly weathered, the lenticular to spheroidal fragments may be a phenomena of shearing and weathering.
 - (12) METAVOLCANICS (Same as 8), light greenish gray to tan, moderately to highly weathered.
 - (13) QUARTZ VEINS, white and reddish brown, they consist of fractured and weathered fragments of white igneous quartz in a matrix of reddish brown moderately to highly plastic clay, the veins and seams vary from 0.2 to 1.0 foot wide.
 - (14) METAVOLCANICS (Gradational with 11), yellowish brown, altered, moderately to highly weathered and soft, moderately foliated, iron oxide stained from weathered pyrite.
 - (15) METAVOLCANICS (Tuff or dike rock), tan to greenish gray, fine grained, massive, moderately soft, moderately jointed, moderately weathered.
 - (16) METAVOLCANICS (Tuff and breccia), grayish green to brownish green, non-uniform fragmental texture, some weathered-out quartz and calcite amygdulae, rock is moderately soft to hard, slightly to moderately weathered, moderately jointed and massive.
 - (17) METAVOLCANICS (Same as 16), grayish green, fresh or nearly fresh fragments or areas, mostly calcite and quartz amygdaloidal rock with thin calcite veins and stringers between fragments, abundant finely disseminated pyrite grains, hard, broken surfaces show rough cleavage.
 - (18) METAVOLCANICS (Same as 16), moderately weathered, slightly foliated.
 - (19) METAVOLCANICS, light green with patches of ochre and brownish yellow, highly altered and highly weathered rock, soft to moderately soft, slightly foliated in places at about N.10°W., 80°SE, rock is similar to number 16.
 - (20) METAVOLCANICS (Tuff), light and dark greenish gray, very fine grained groundmass with scattered small white phenocrysts (probably plagioclase), moderately hard, rock contains scattered amygdulae with powdery weathered pyrite, slightly weathered, moderately jointed, joints irregular and covered with brownish red iron oxide coatings.
 - (21) METAVOLCANICS (Agglomerate), grayish green, fine grained groundmass with coarse, lenticular plagioclase pyritic fragments from 3 inch to 6 inch in diameter, moderately weathered, moderately foliated groundmass, irregular joints with dark reddish brown iron oxide coatings.
 - (22) METAVOLCANICS, light grayish green, fine to coarse moderately foliated groundmass with 1/4 inch to 1/2 inch shaped, hard, dark green augen, highly spheroidal.
 - (23) METAVOLCANICS (Same as 20), no plagioclase phenocrysts.
 - (24) CLAY SEAMS, light tan to brown, soft to stiff, moderate plasticity, some decomposed clayey rock clay seams at 254 to 260 feet, appear to be decomposed rock along joints, seams vary from 1 to 2 foot wide.

NOTES

Numbers 1 to 42 along top of trench indicate the cent 42 sets of shoring used for trench wall support.

Trench bottom was not excavated to refusal by backhoe except at a few places.



CANICS, light grayish green, fine to coarse grained, slightly foliated groundmass with 1/4 inch to 1/2 inch oval hard, dark green augen, highly spheroidally weathered.

CANICS (Same as 20), no plagioclase phenocrysts.

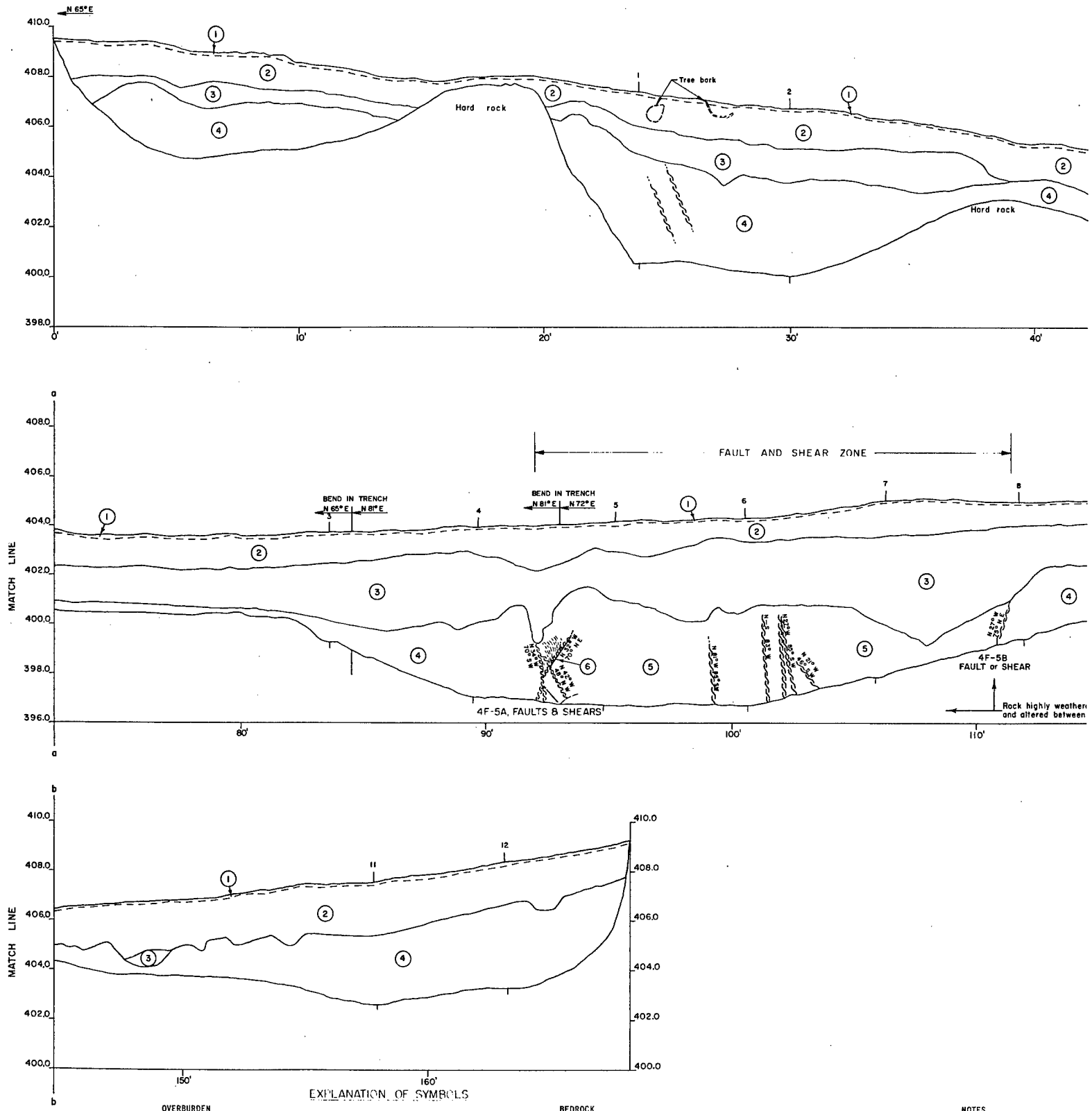
AMS, light tan to brown, soft to stiff, slight to a plasticity, some decomposed clayey rock, some seams at 254 to 260 feet, appear to consist of ised rock along joints, seams vary from 0.1 to 0.3 side.

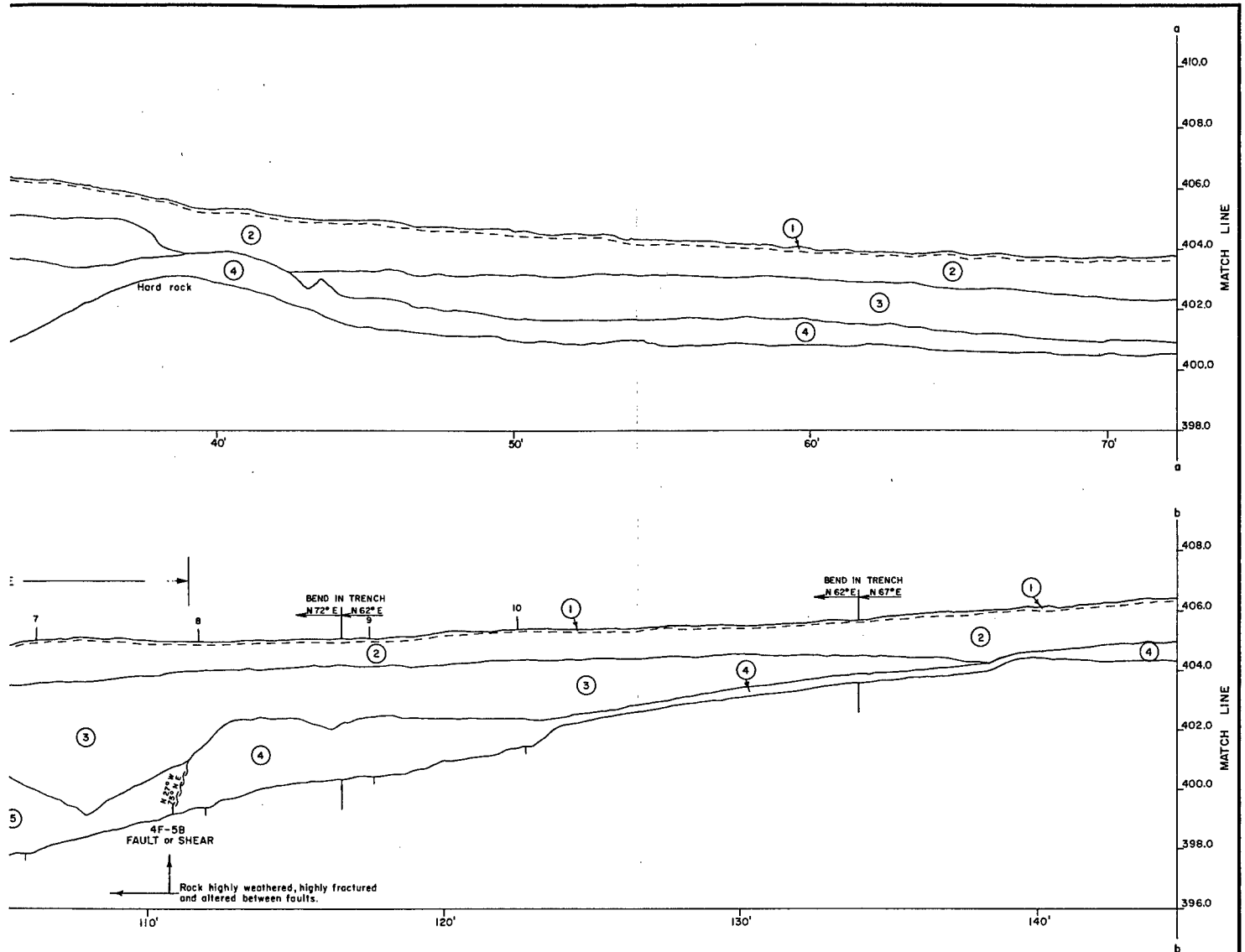
NOTES

N2 along top of trench indicate the center location of boring used for trench wall support.

was not excavated to refusal by backhoe (Case 5808) new places.

REVISION	DATE	DESCRIPTION	BY
DEPARTMENT OF THE ARMY SACRAMENTO DISTRICT, CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA			
DESIGNED BY: DRAWN BY: D. W. Paige CHECKED BY: R. J. Anderson PREPARED BY: R. L. Teed J. J. Gewerth, K. Y. Buer SUBMITTED BY: J. S. Teed CORPS GEOLOGY SECTION		MARYSVILLE LAKE PROJECT PARKS BAR ALTERNATE FAULT EVALUATION STUDY LOG OF TRENCH 4F-4 SOUTH WALL	
APPROVAL RECOMMENDED: CHIEF/PHYS. & MATH. BRANCH PREPARED UNDER THE DIRECTION OF DONALD M. O'SHEI COL., CORPS OF ENGINEERS, U. S. A.		APPROVED: [Signature] DATE: 39/10 SCALE: AS SHOWN SHEETS: 39/6 to 39/11 SHEET NO.: 39/10	





NOTES

to 12 along top of trench indicate the center location of shoring used for trench wall support.

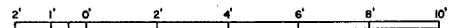
ton was excavated to refusal by backhoe (Case 5808) except and 114 feet.

ized pine bark found between 24 and 28 feet in the residual ellaved to be contaminated because it was too close to the id therefore it was not carbon dated.

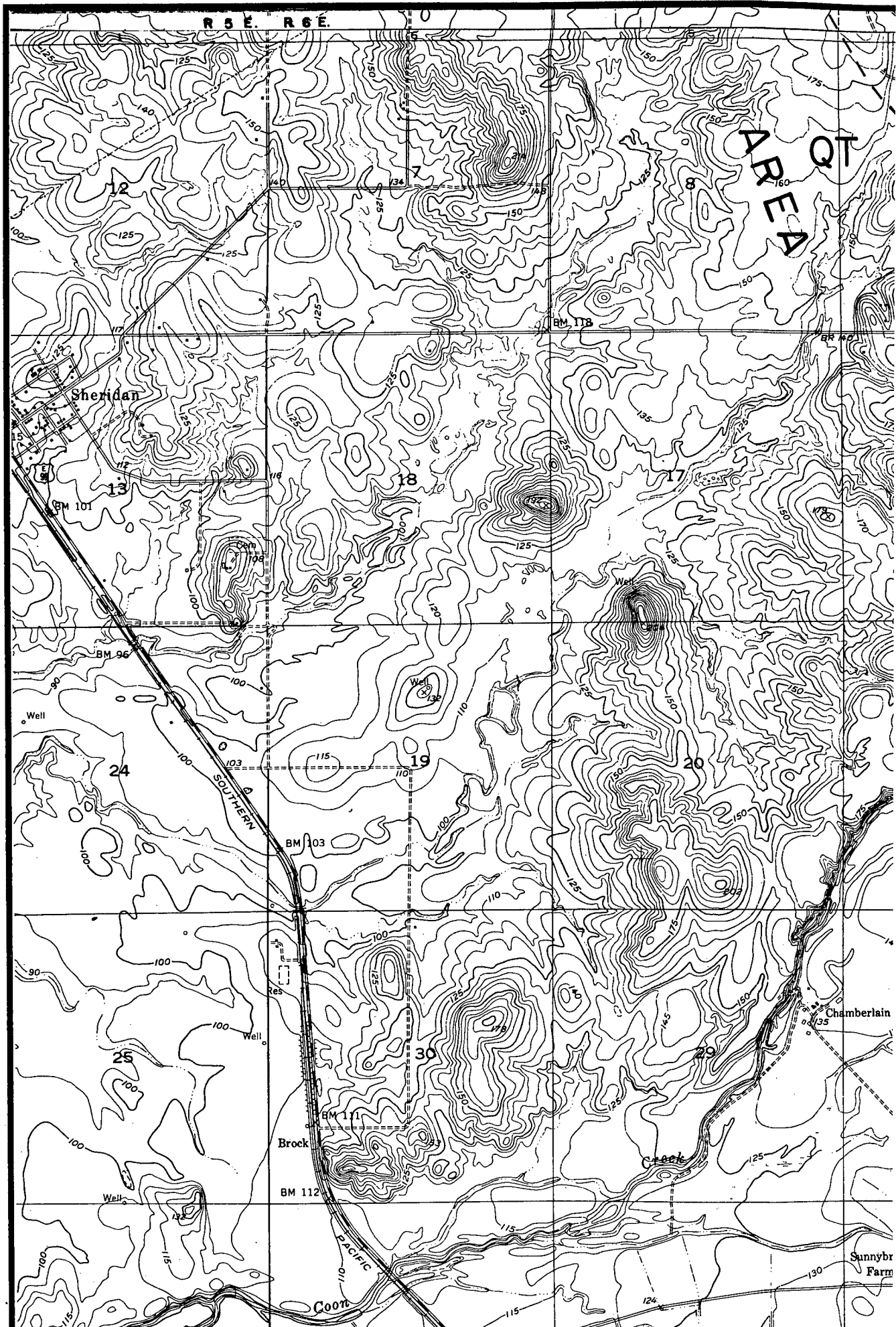
ion of movement could not be determined for either feature F-5B.

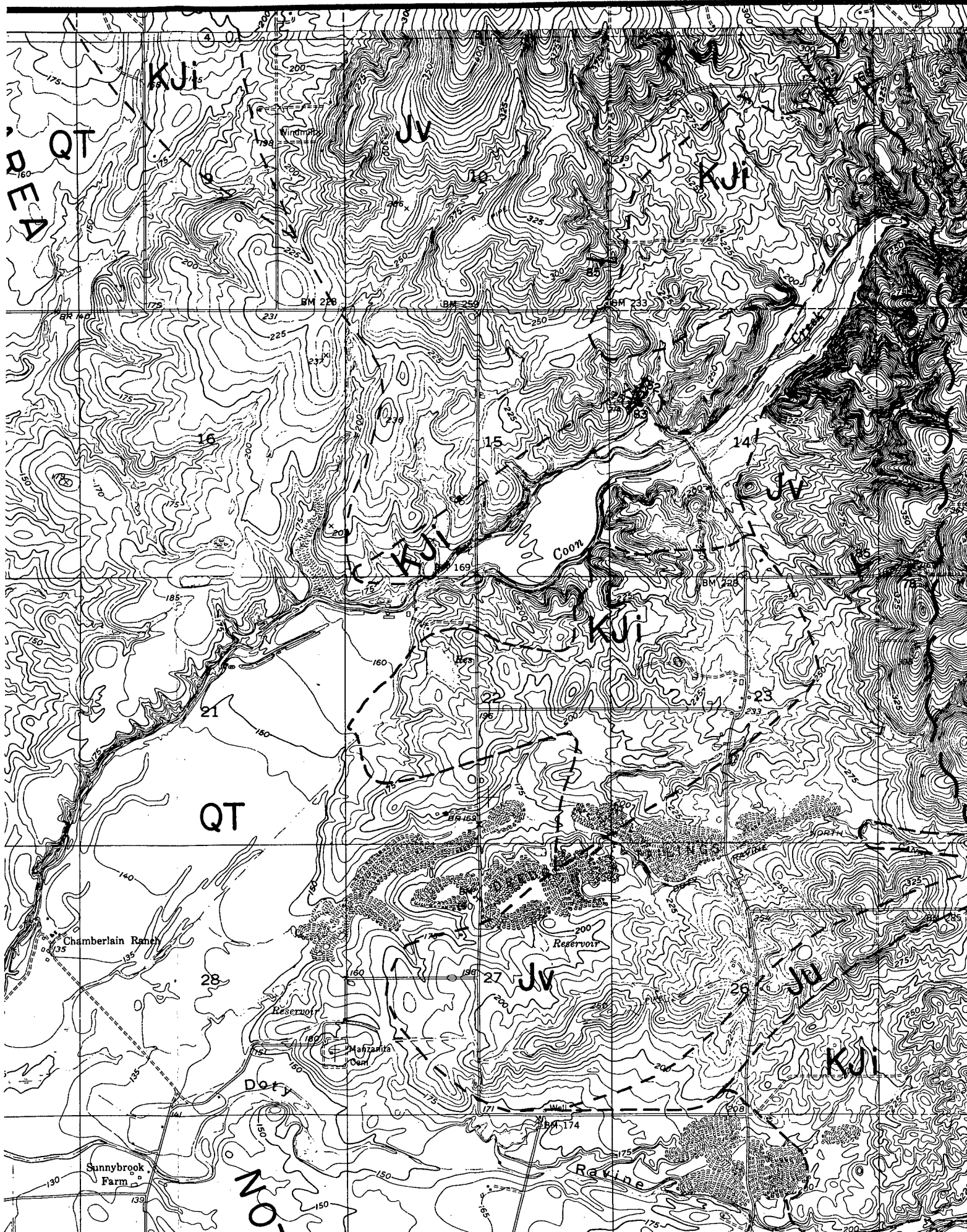
- Geologic contact.
- - - Approximate geologic contact.
- N 27° W
75° NE Shear with strike and dip.
- ~~~~~ Shear.

GRAPHIC SCALE

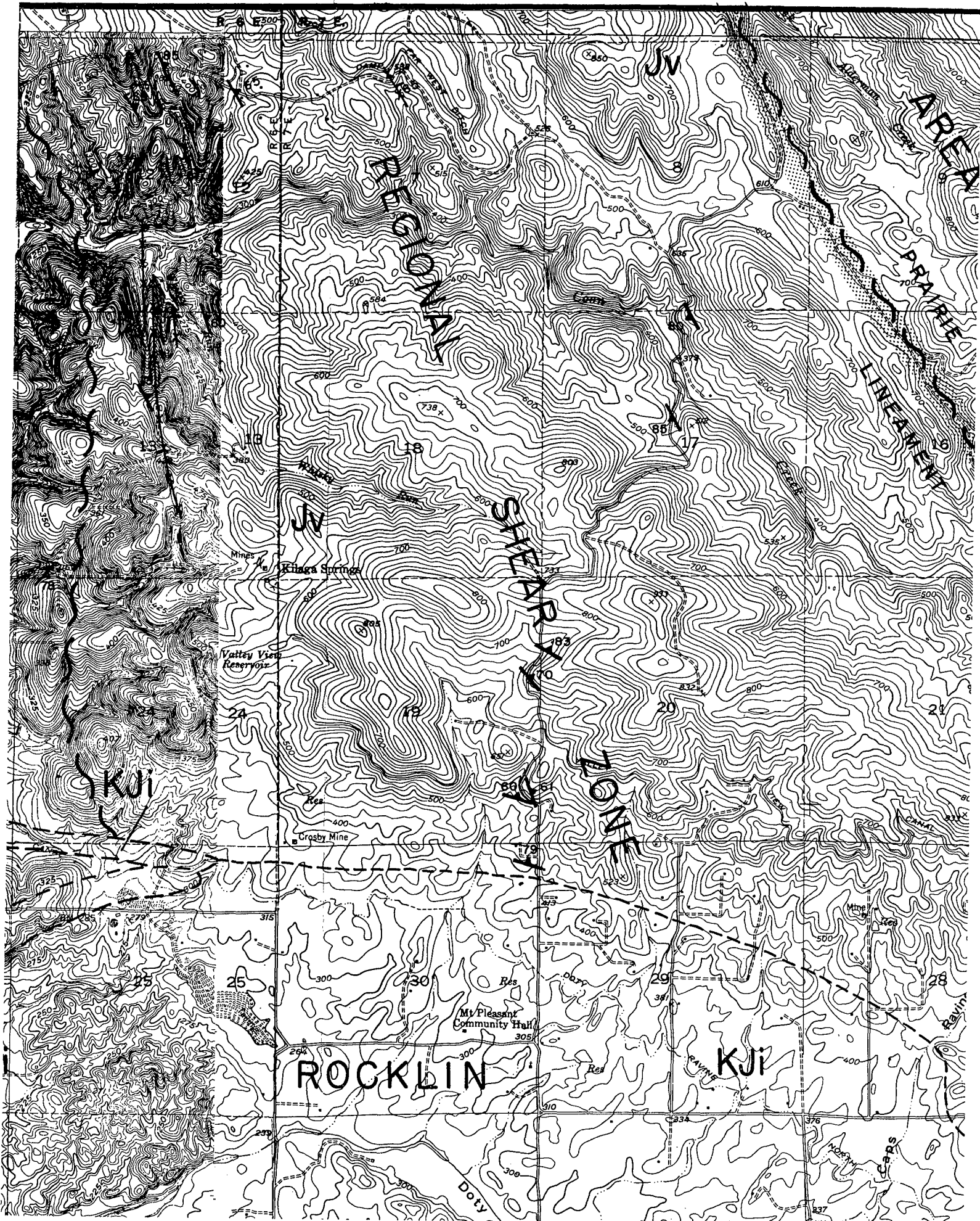


DESIGNED BY:	DEPARTMENT OF THE ARMY SACRAMENTO DISTRICT, CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA	
DRAWN BY: D. W. Paige	MARYSVILLE LAKE PROJECT PARKS BAR ALTERNATE	
CHECKED BY: R. J. Anderson	FAULT EVALUATION STUDY	
PREPARED BY: R. L. Treat J. A. Musto, A. B. Price	LOG OF TRENCH 4F-5 SOUTH WALL	
SUBMITTED:	APPROVED:	DATE:
CHIEF ENGINEER'S OFFICE	DISTRICT ENGINEER	
PREPARED UNDER THE DIRECTION OF	SCALE: AS SHOWN	SHEET NO.
DONALD M. O'SHEI	FILE NO. YU-4-20-39	SHEETS
COL, CORPS OF ENGINEERS, U. S. A.	39/6 to 39/11	39/11

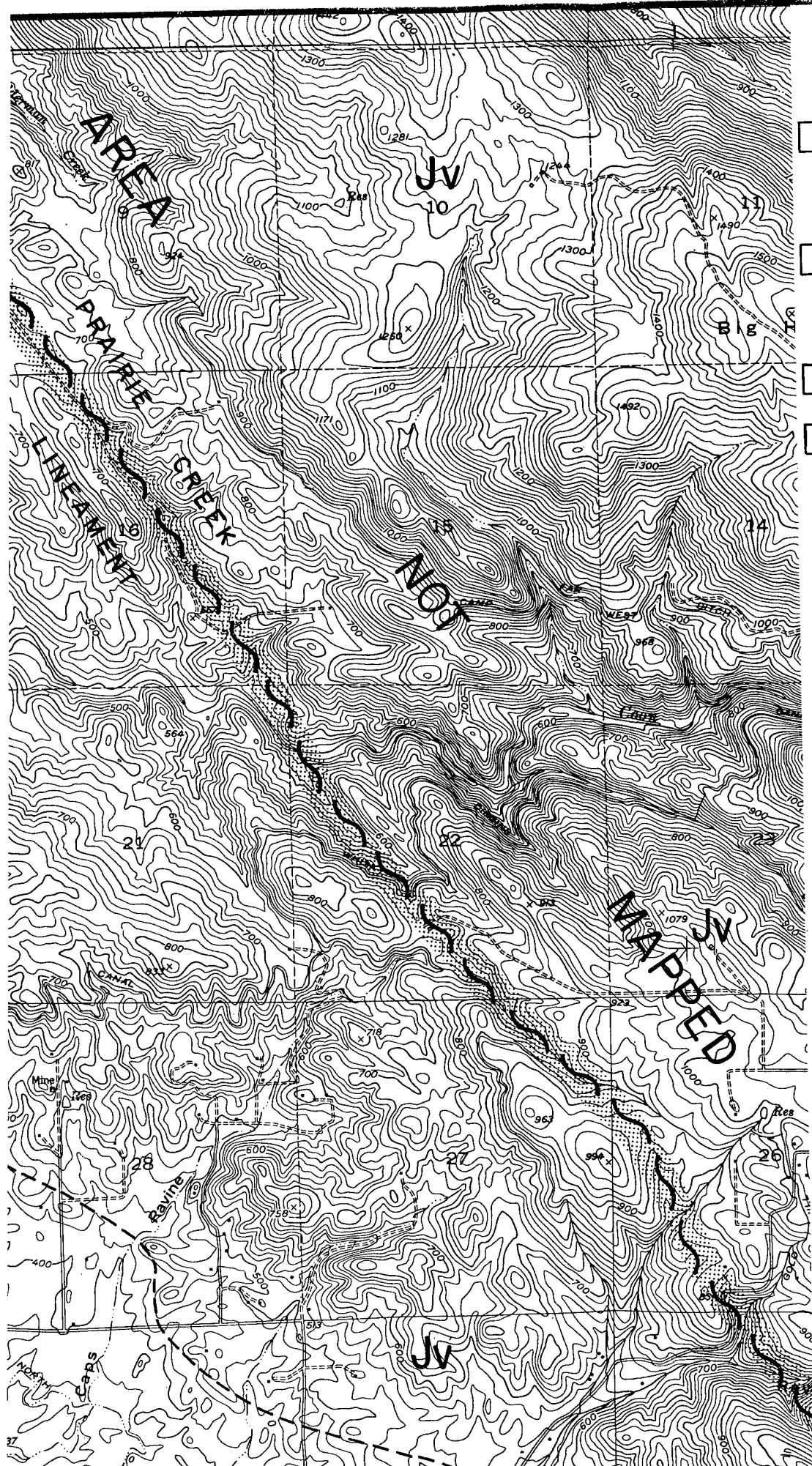




ALUE ENGINEERING PAYS 3



EXPLAN



QT

TER
Sedimentary and vol
western margin of t

Kji

JUR
Mesozoic intrusive
granodiorite, tonal

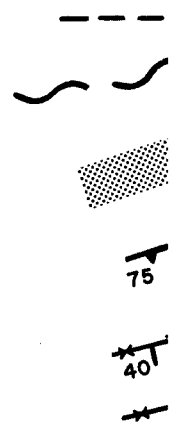
Ju

Metasedimentary roc
contact migmatite

Jv

Metavolcanic rocks.
pillowed and non-pi
crystal and lithic
diabasic to dacitic
are described in th

Geologic contacts
California, Sacram
Geologic symbols u
geological mapping
"AREA NOT MAPPED".



EXPLANATION OF SYMBOLS

TERTIARY TO QUATERNARY

QT

Sedimentary and volcanic deposits. Undifferentiated along the western margin of the map; locally overlies metavolcanic bedrock.

JURASSIC TO CRETACEOUS

KJi

Mesozoic intrusive igneous rocks. Includes variations of granite, granodiorite, tonalite, gabbro, diorite, and quartz.

UPPER JURASSIC

Ju

Metasedimentary rocks (?). Possibly a schistose or gneissose contact migmatite on the northwest side of the Rocklin Pluton.

Jv

Metavolcanic rocks. Chiefly metamorphosed basaltic to andesitic, pillowed and non-pillowed flows and pyroclastics including crystal and lithic tuffs, and tuff breccias or agglomerates with diabasic to dacitic dikes. Five groups of metavolcanic rocks are described in the project area (plate III).

NOTES

Geologic contacts are generalized from the Geologic Map of California, Sacramento Sheet (Strand and Koenig, 1965). Geologic symbols used are from Clark, 1976. Only reconnaissance geological mapping was done in some areas which are designated "AREA NOT MAPPED".

--- Approximate geologic contact

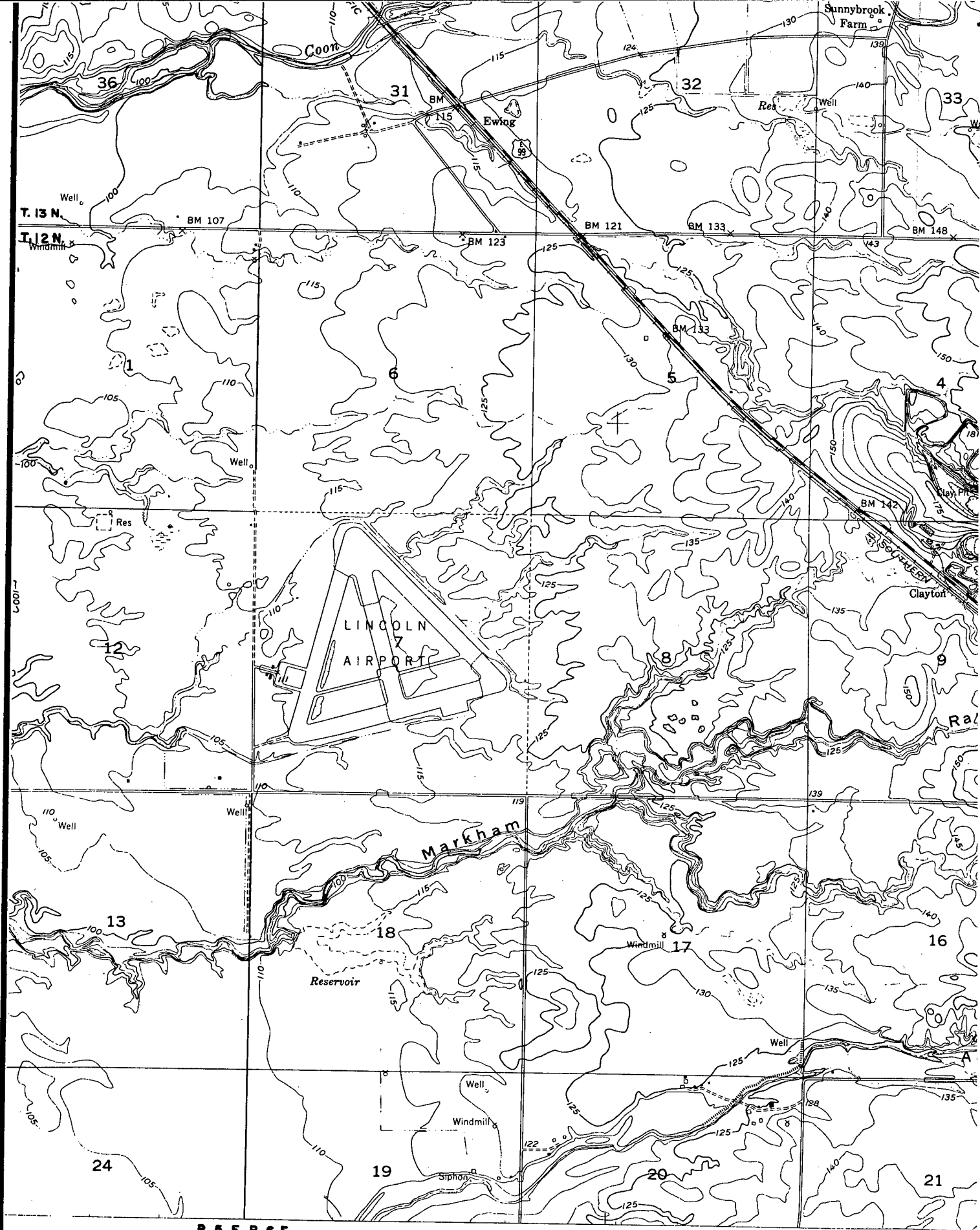
~ ~ ~ Regional shear zone boundary

▨ General location of lineament

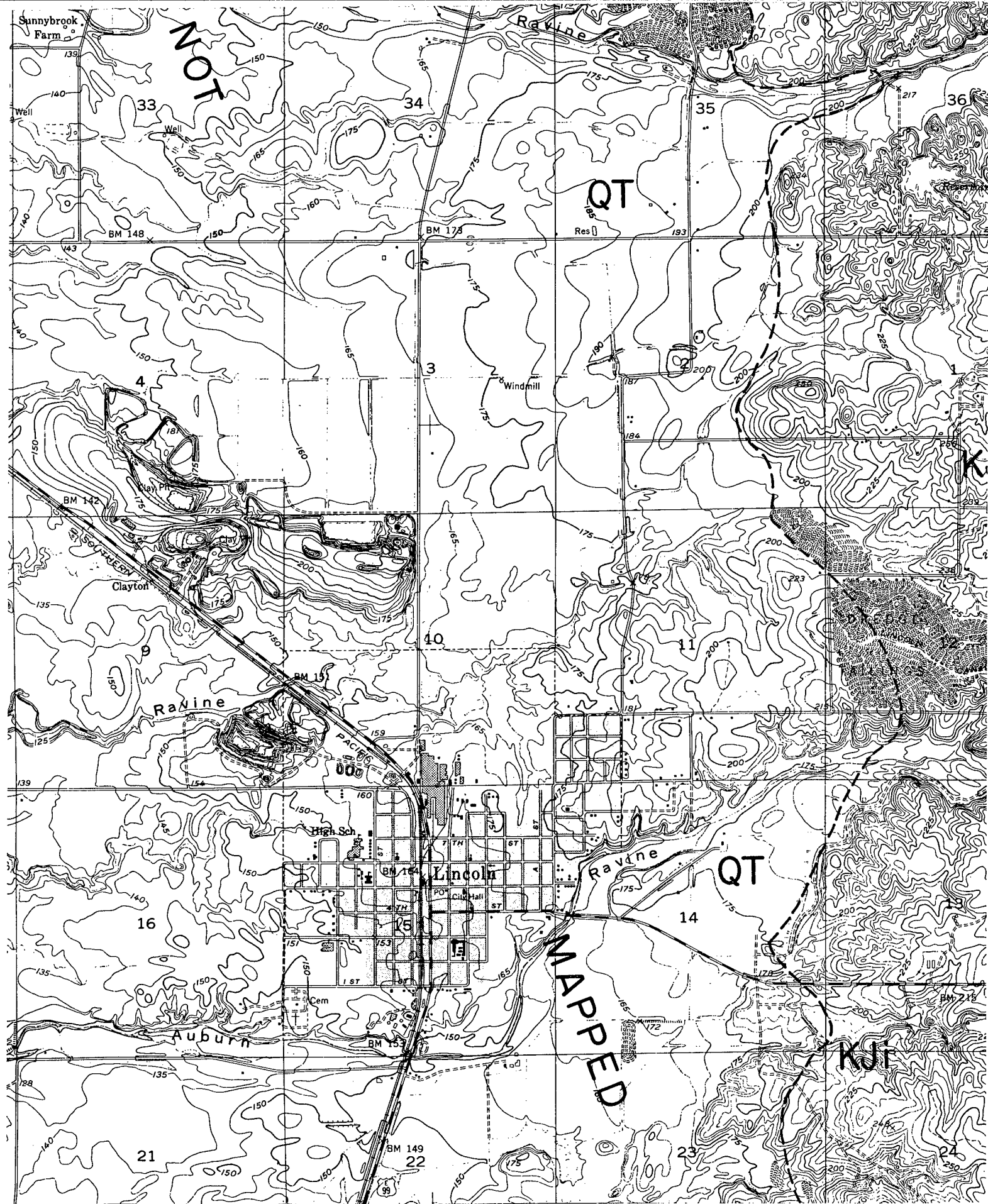
↘
75 Strike and dip of foliation

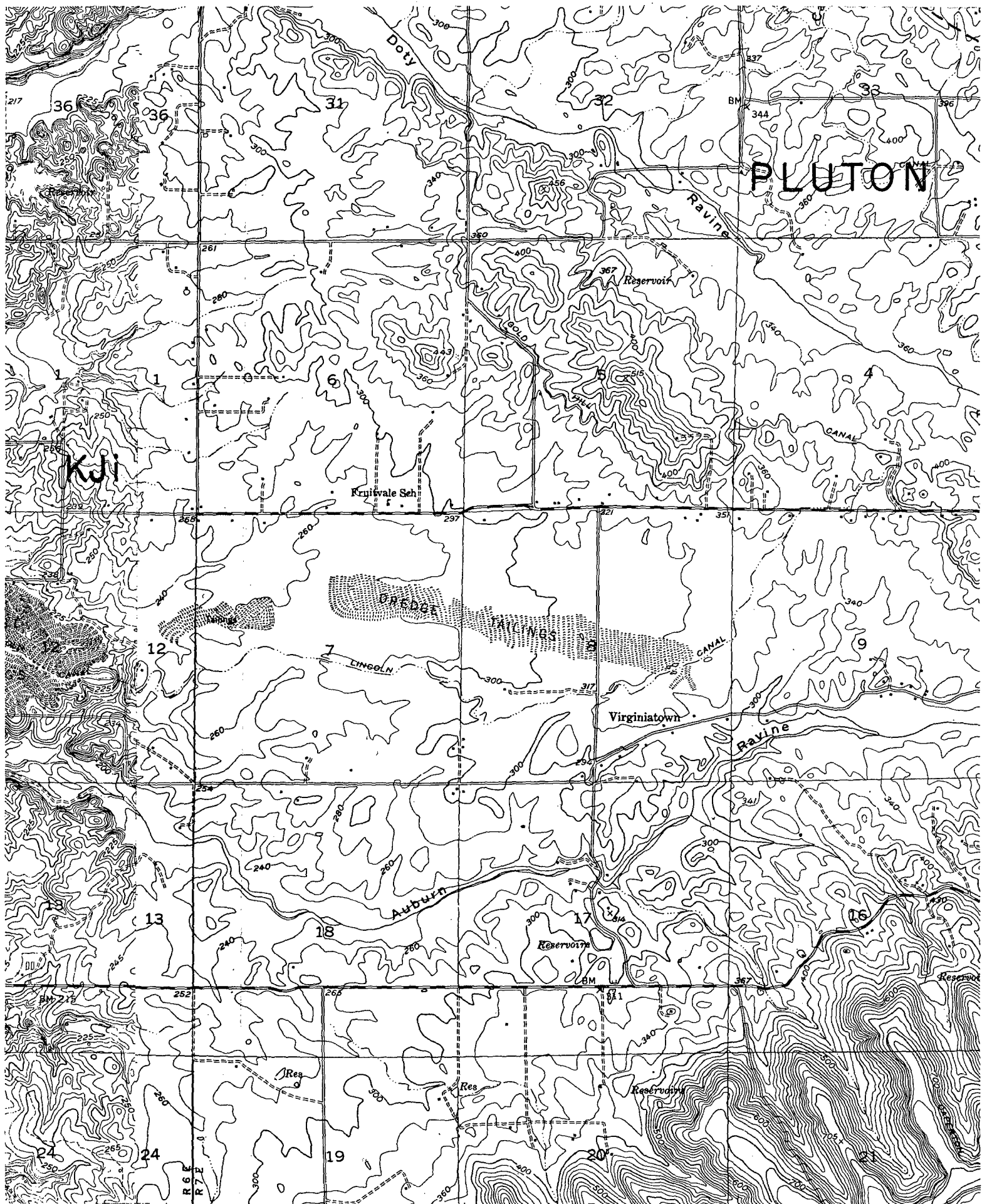
↘
40 Strike and dip of dike

↘ Strike of dike

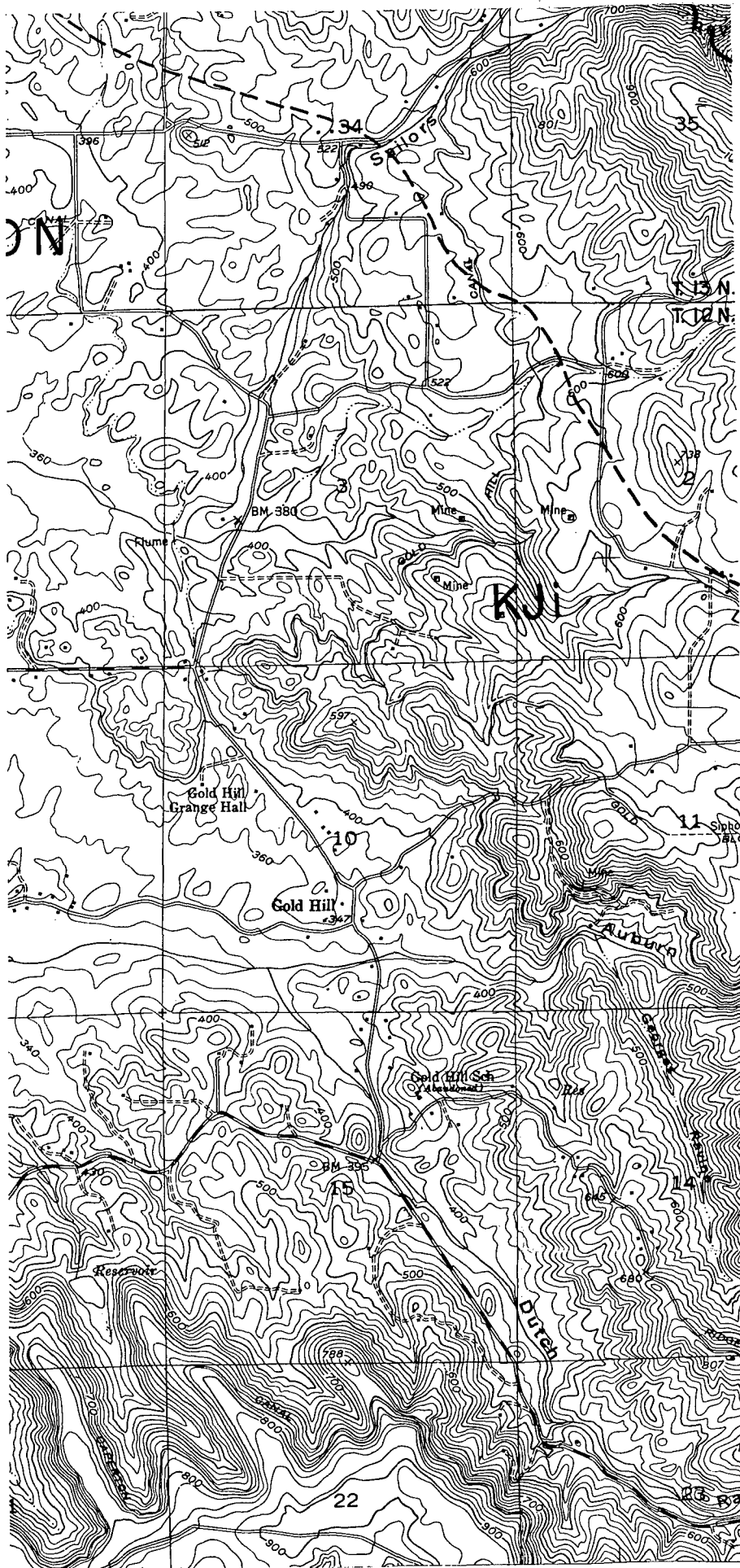


R. 5 E. R. 6 E.





R. 6 E. R. 7 E.

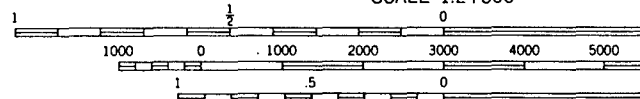


This map is a composite of U.S. quadrangles, Lincoln and Gold Hill California 7.5 minute series.

ROAD CLASSIFICATION

HARD-SURFACE ALL WEATHER ROADS		DRY WEATHER ROADS
Heavy-duty	<u>4 LANE 16 LANE</u>	Improved dirt
Medium-duty	<u>4 LANE 16 LANE</u>	Unimproved dirt
Loose-surface, graded, or narrow hard-surface		
U. S. Route	State Route	

SCALE 1:24 000



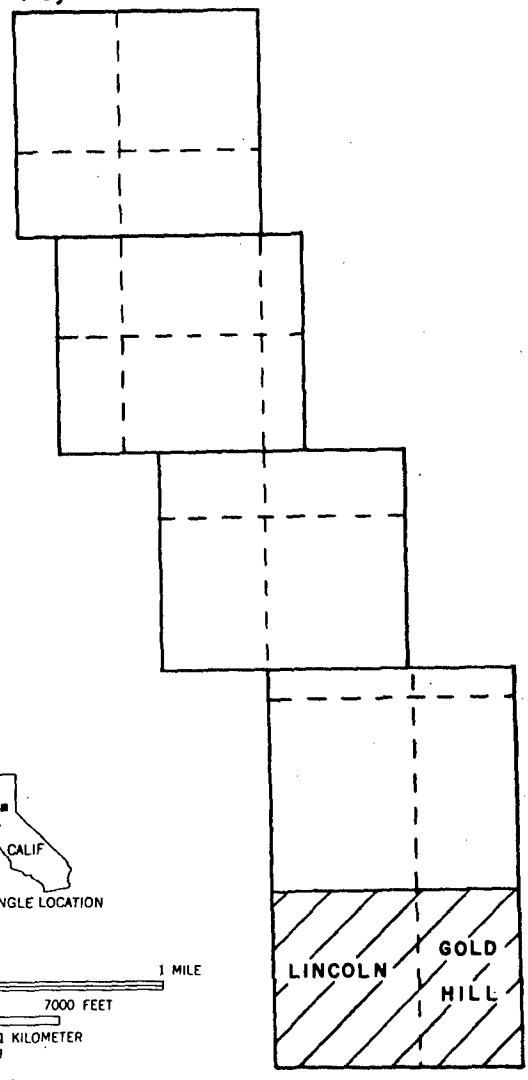
REVISION	DATE	

DEPARTMENT OF



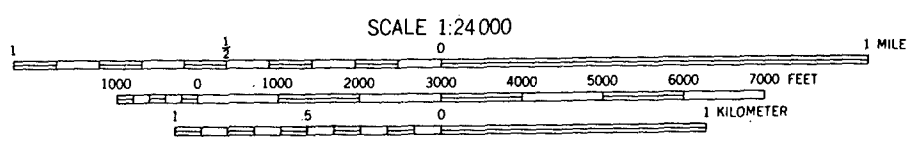
This map is a composite of U.S.G.S. quadrangles, Lincoln and Gold Hill, California 7.5 minute series.

Key to sheets



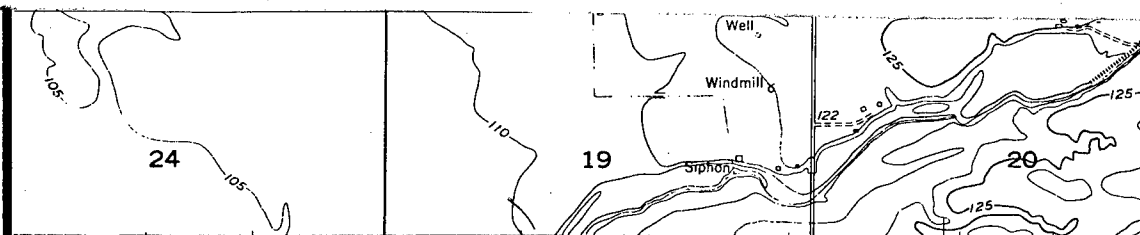
ROAD CLASSIFICATION

- | | | | |
|---|-----------------------|-------------------|-------|
| HARD-SURFACE ALL WEATHER ROADS | | DRY WEATHER ROADS | |
| Heavy-duty | <u>4 LANE 16 LANE</u> | Improved dirt | ----- |
| Medium-duty | <u>4 LANE 16 LANE</u> | Unimproved dirt | ----- |
| Loose-surface, graded, or narrow hard-surface - - - - | | | |
| U. S. Route | | State Route | |

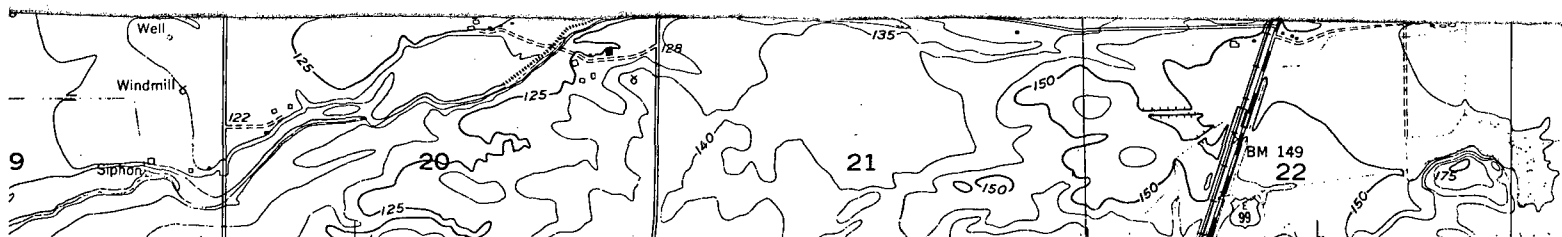


REVISION	DATE	DESCRIPTION	BY	BY

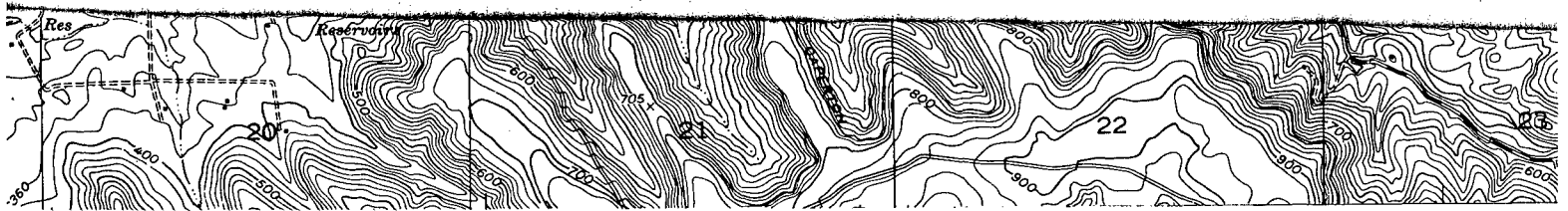
DEPARTMENT OF THE ARMY

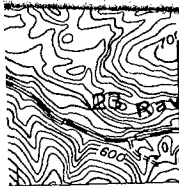


R. 5 E. R. 6 E.

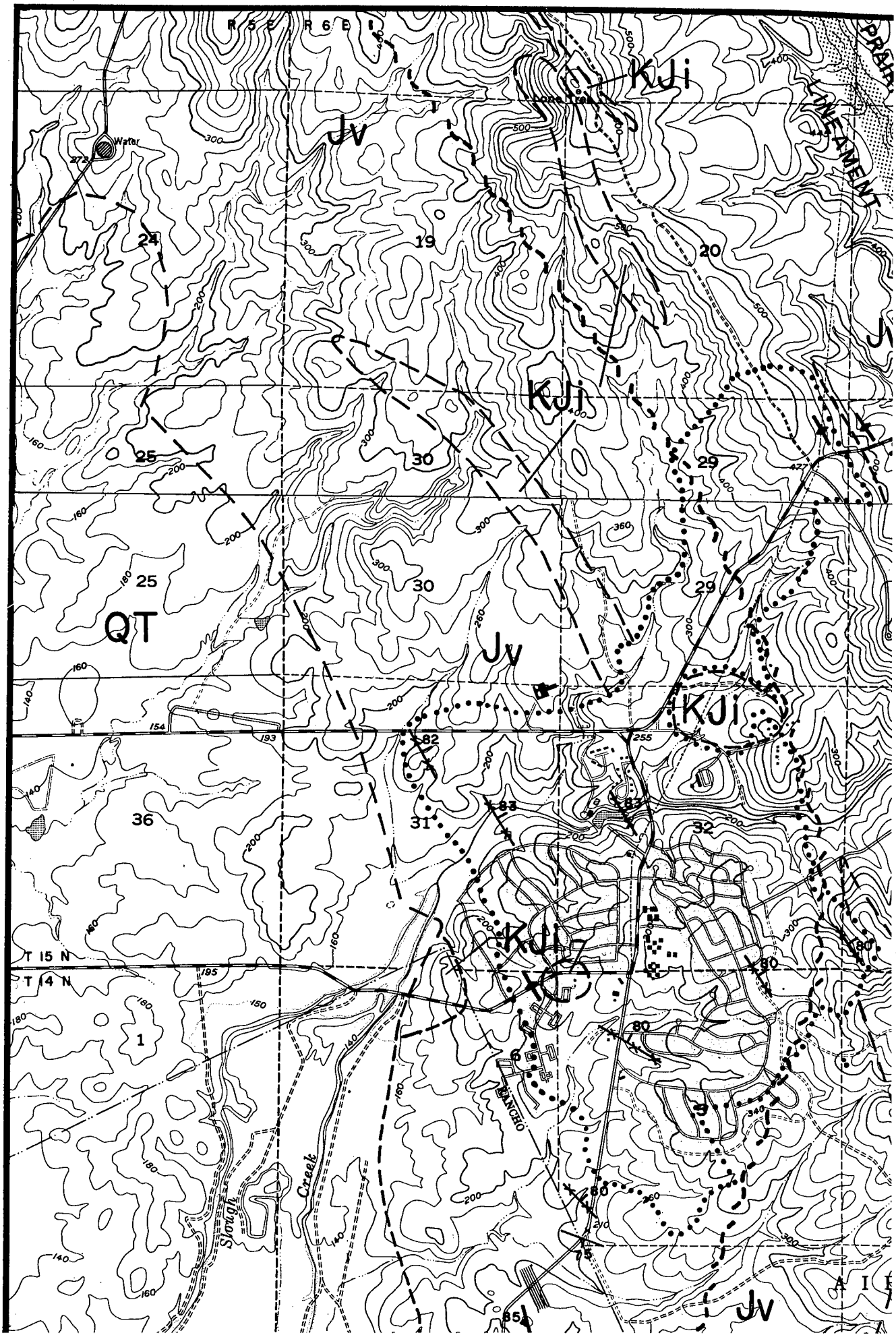


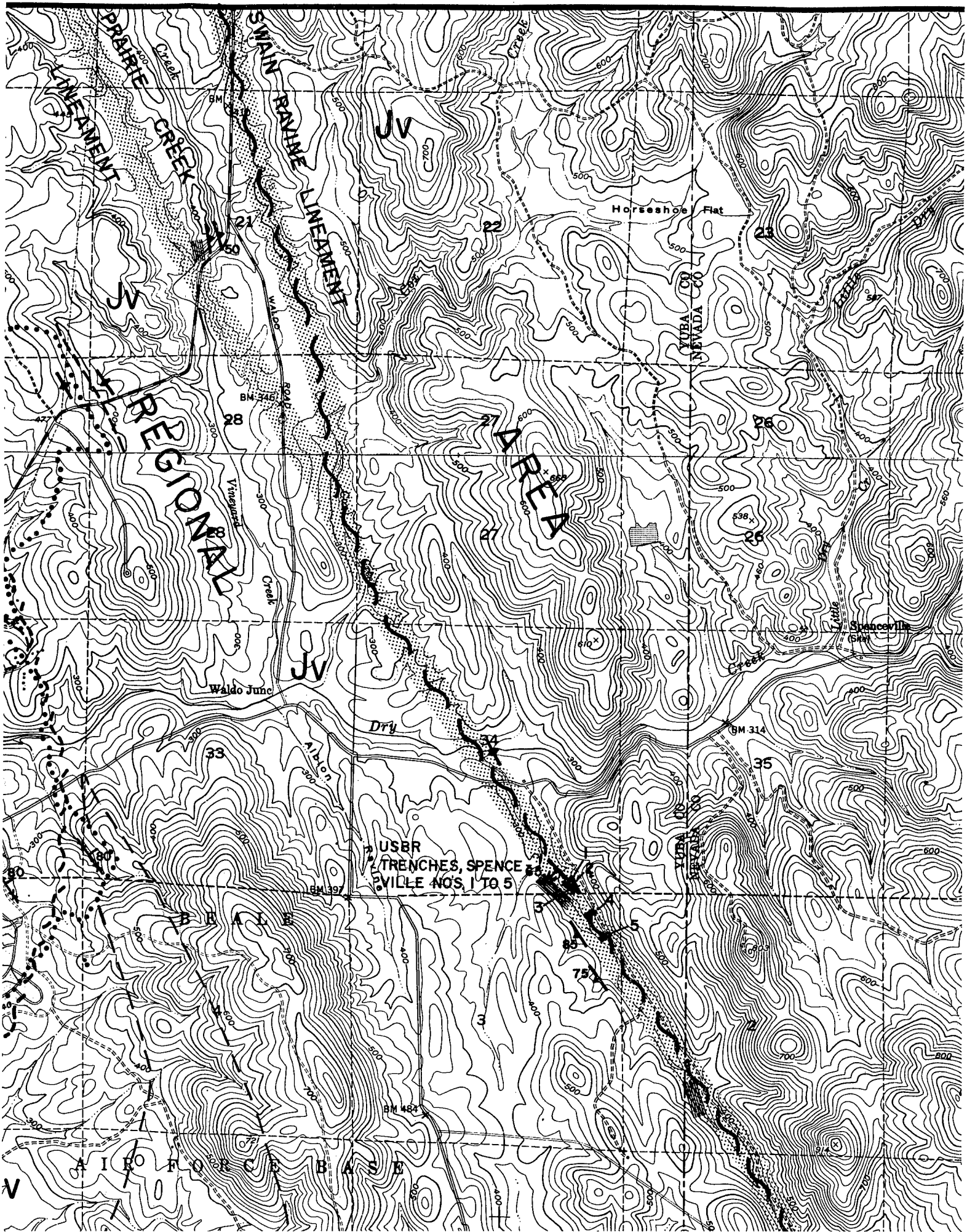




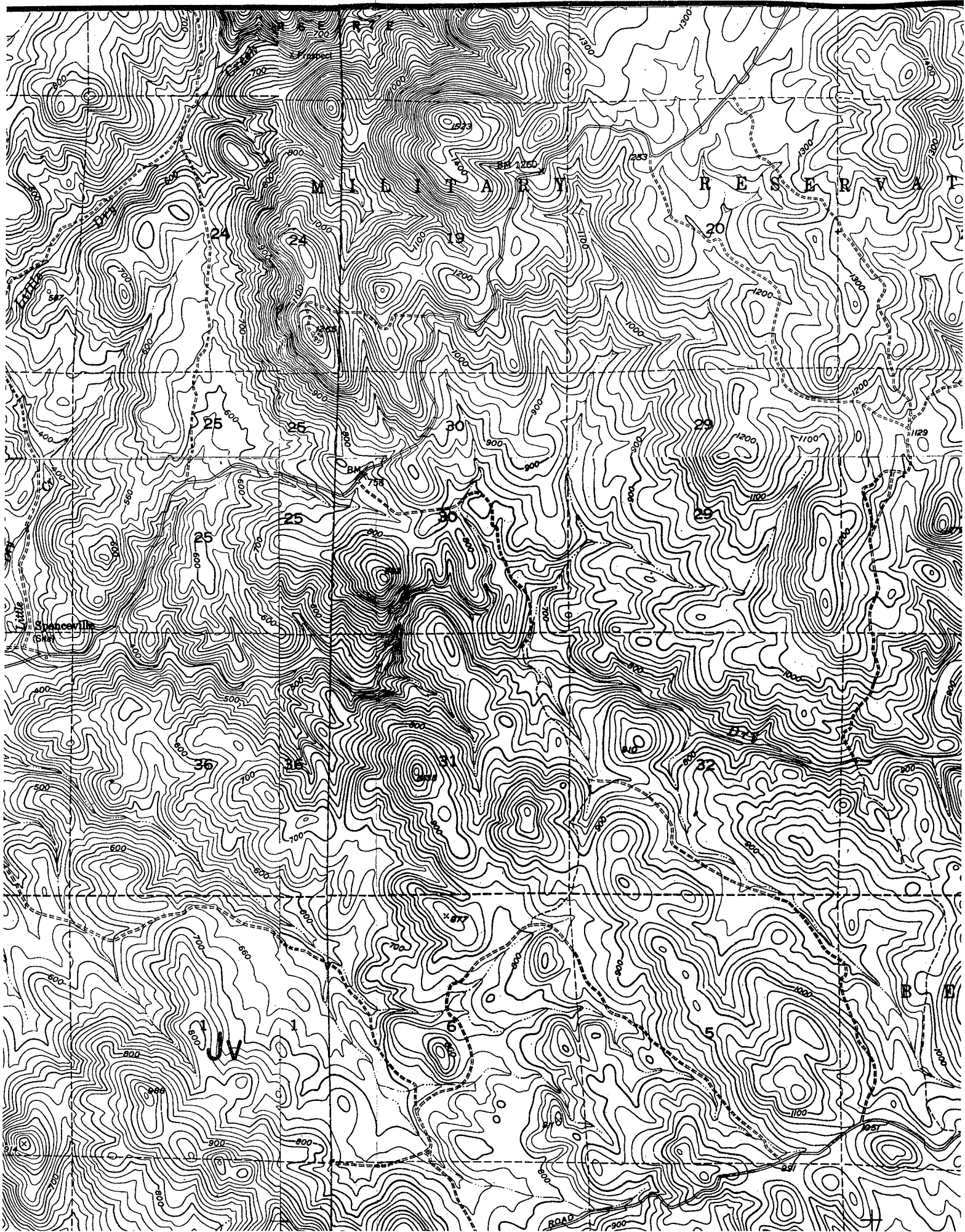


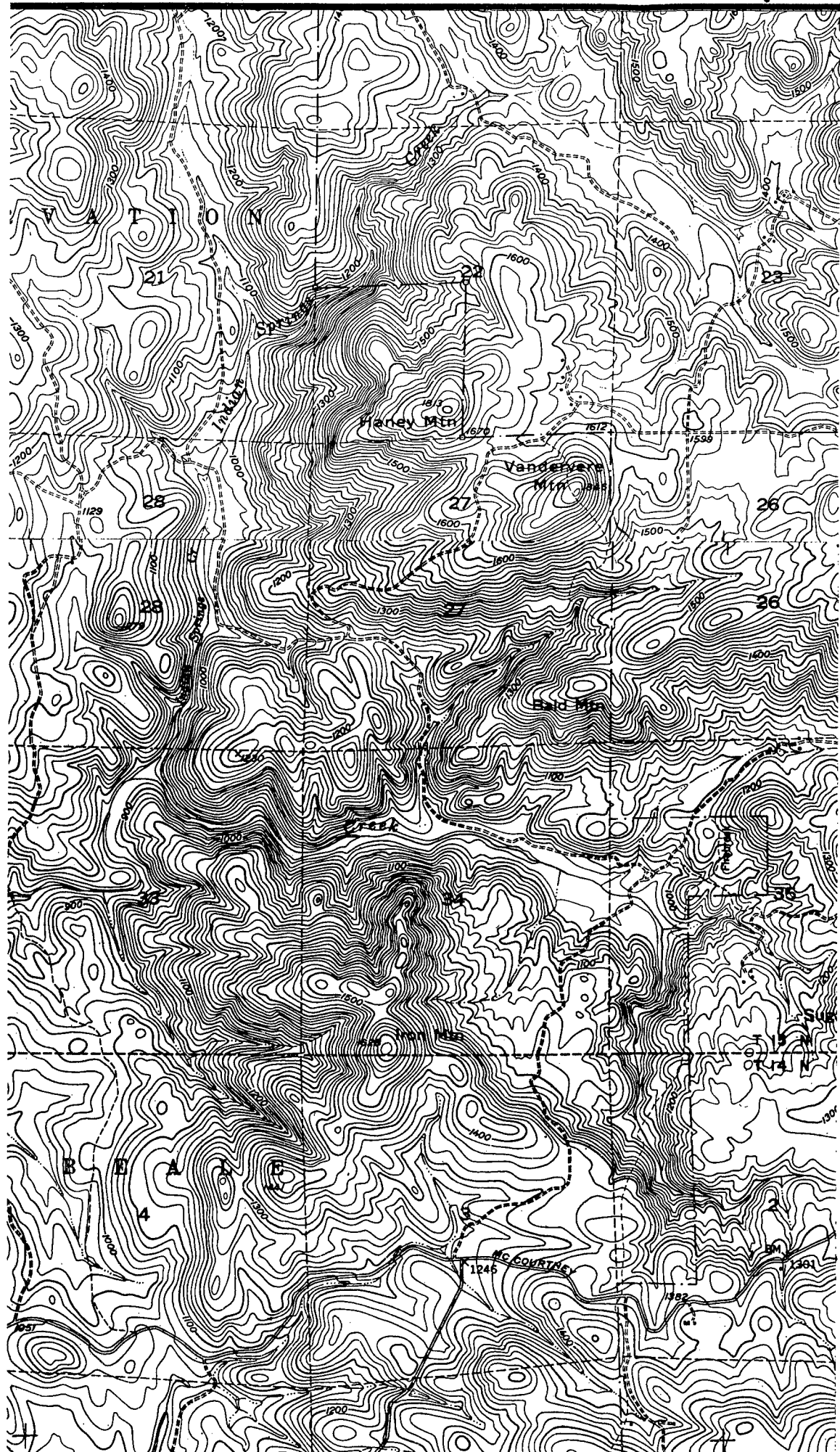
REVISION	DATE	DESCRIPTION	BY	BY
<div>DEPARTMENT OF THE ARMY SACRAMENTO DISTRICT, CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA</div> <div>DESIGNED BY: _____ DRAWN BY: <i>D. W. Paige</i> CHECKED BY: <i>R. J. Anderson</i> PREPARED BY: <i>R. Treat, K. Euer, J. Gewerth, A. Price, J. Musto</i> SUBMITTED: <i>G. J. Guthrie</i> CHIEF, GEOLOGY SECTION</div> <div>MARYSVILLE LAKE PROJECT PARKS BAR ALTERNATE REGIONAL GEOLOGY FAULT EVALUATION STUDY</div> <div>APPROVAL RECOMMENDED: <i>J. Giandrone</i> CHIEF, FDNS & MAT'L BRANCH PREPARED UNDER THE DIRECTION OF DONALD M. O'SHEI COL., CORPS OF ENGINEERS, U. S. A.</div> <div>APPROVED: <i>R. J. Wasny</i> CHIEF, ENGINEERING DIVISION DATE: _____ SCALE: AS SHOWN FILE NO. YU-4-20-39 SHEETS 39/1 to 39/5 SHEET NO. 39/1</div>				





VALUE ENGINEERING PAYS 3





- QT Sedimentary ar
western margin
- KJi Mesozoic intru
granite, granc
- Jv Metavolcanic
pillowed and r
crystal and li
diabasic to da
are described

Geologic conta
California, Ch
geologic symb
geological map
"AREA NOT MAP
The northernmc



EXPLANATION OF SYMBOLS

TERTIARY TO QUATERNARY

QT

Sedimentary and volcanic deposits. Undifferentiated along the western margin of map; locally overlies metavolcanic bedrock.

JURASSIC TO CRETACEOUS

Kji

Mesozoic intrusive igneous rocks. Includes variations of granite, granodiorite, tonalite, gabbro, diorite, and quartz.

UPPER JURASSIC

Jv

Metavolcanic rocks. Chiefly metamorphosed basaltic to andesitic, pillowed and non-pillowed flows and pyroclastics including crystal and lithic tuffs, tuff breccias or agglomerates with diabasic to dacitic dikes. Five groups of metavolcanic rocks are described in the project area (Plate III).

NOTES

Geologic contacts are generalized from the Geologic Map of California, Chico Sheet (Burnett and Jennings, 1962). Most geologic symbols used are from Clark, 1976. Only reconnaissance geological mapping was done in some areas which are designated "AREA NOT MAPPED".

The northernmost Kji body on this plate is massive quartz.

--- Approximate geologic contact

~ Regional shear zone boundary

- - - Inferred shear zone boundary

▨ General location of lineament

••• Area of abundant dikes

▨ Altered rock zone

75° Strike and dip of foliation

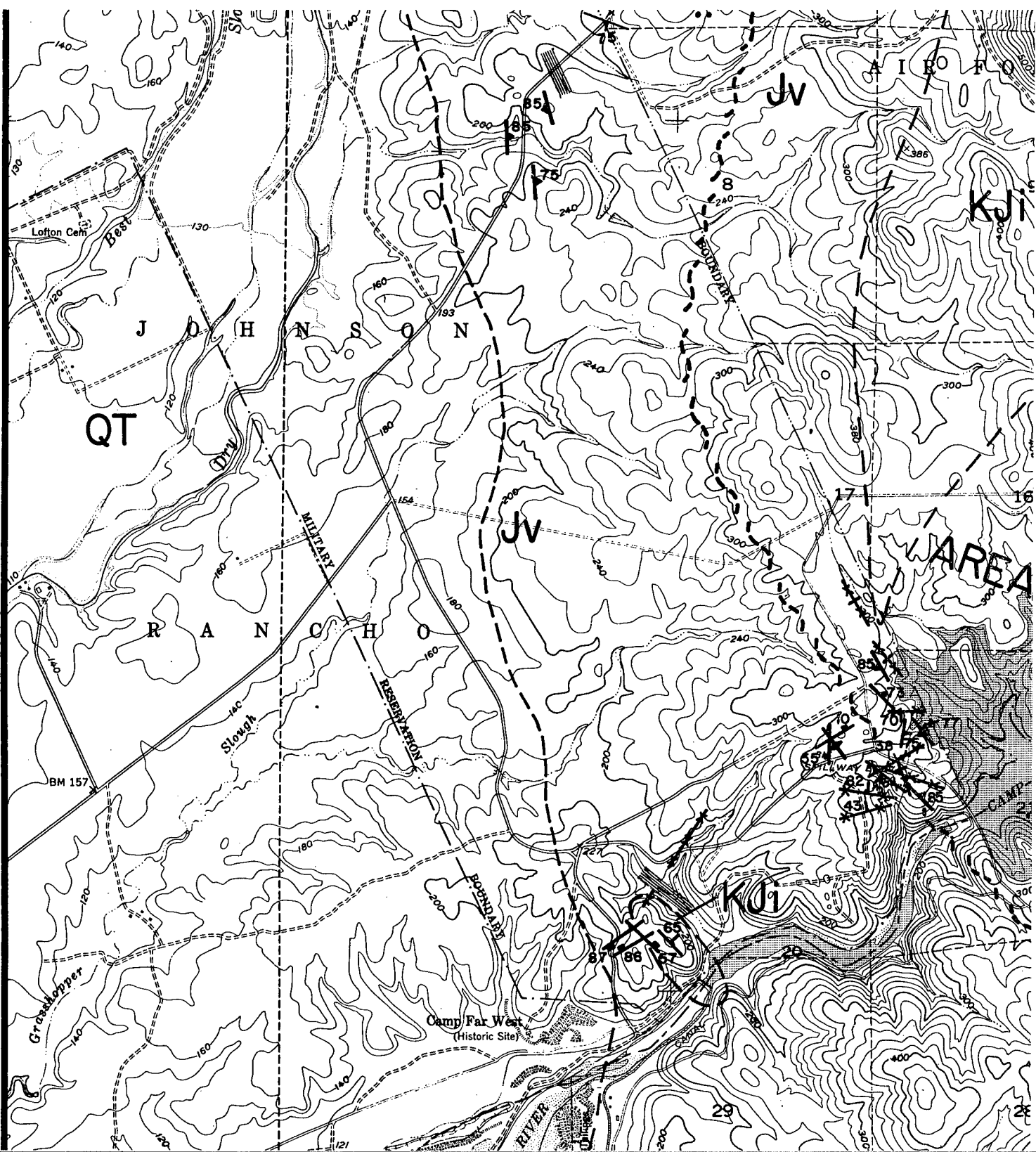
✦ Strike of vertical foliation

55° Strike and dip of bedding

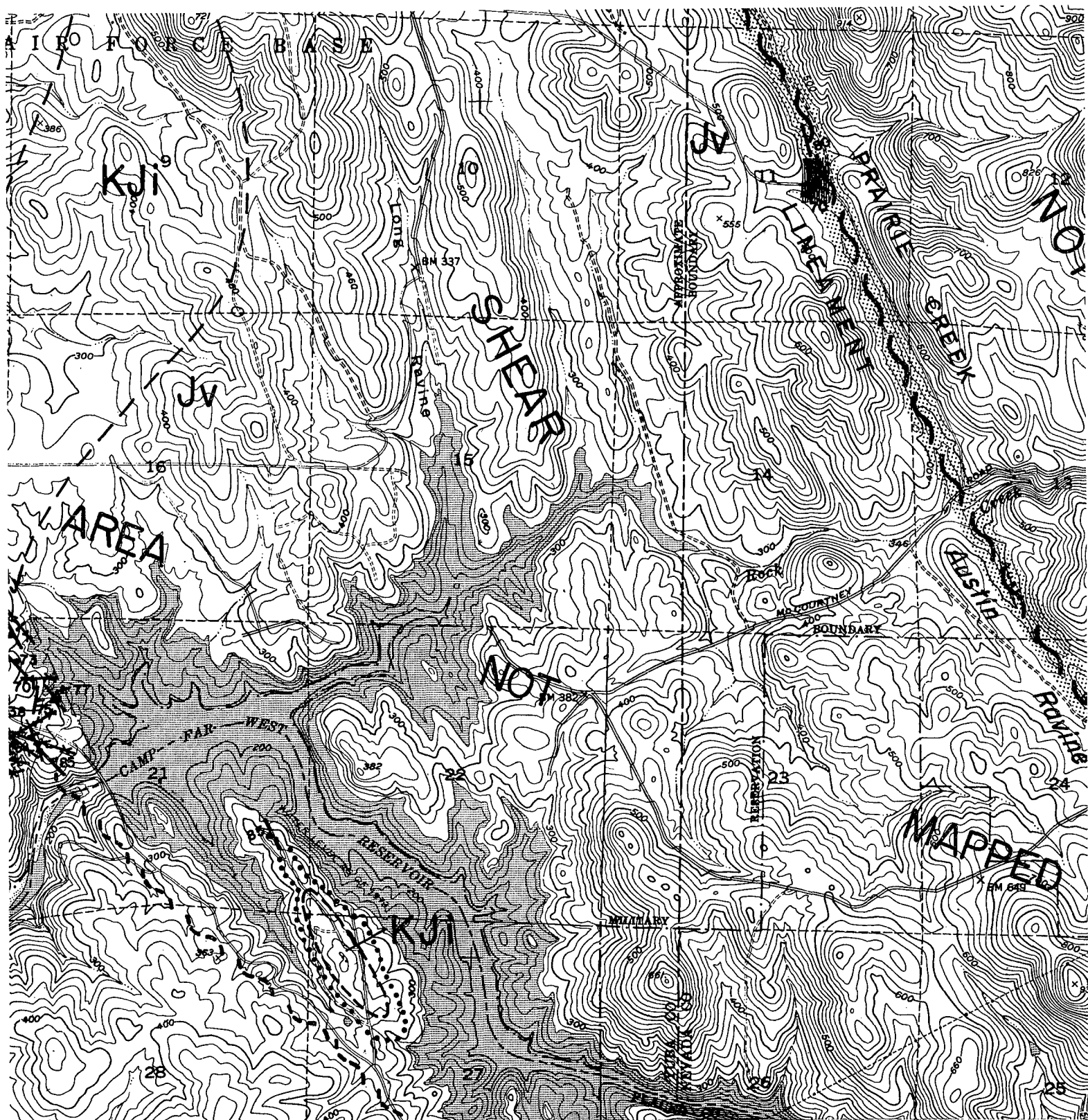
86°/57° Strike and dip of joints

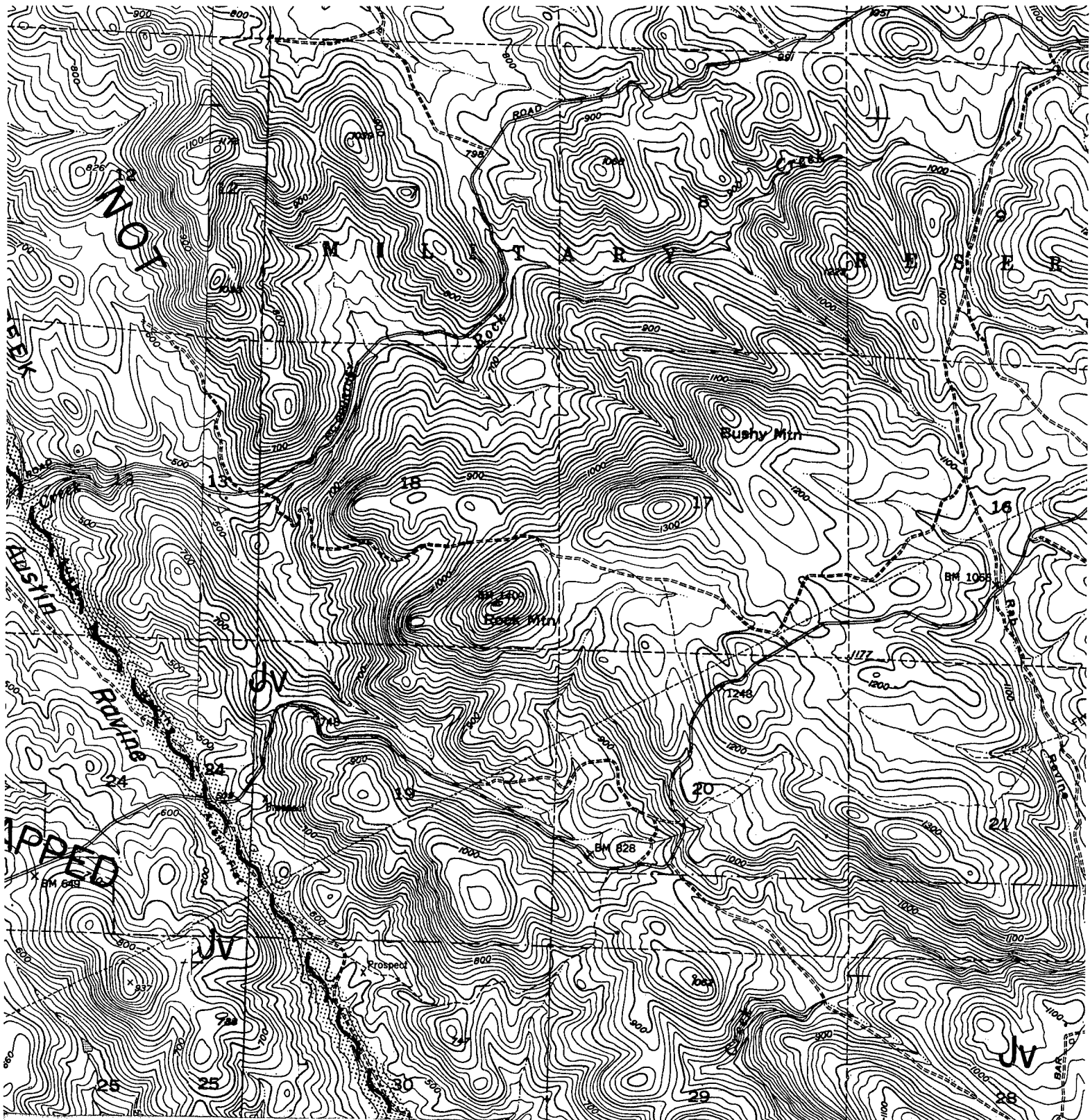
40° Strike and dip of dike

✦ Strike of vertical dike

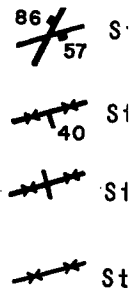
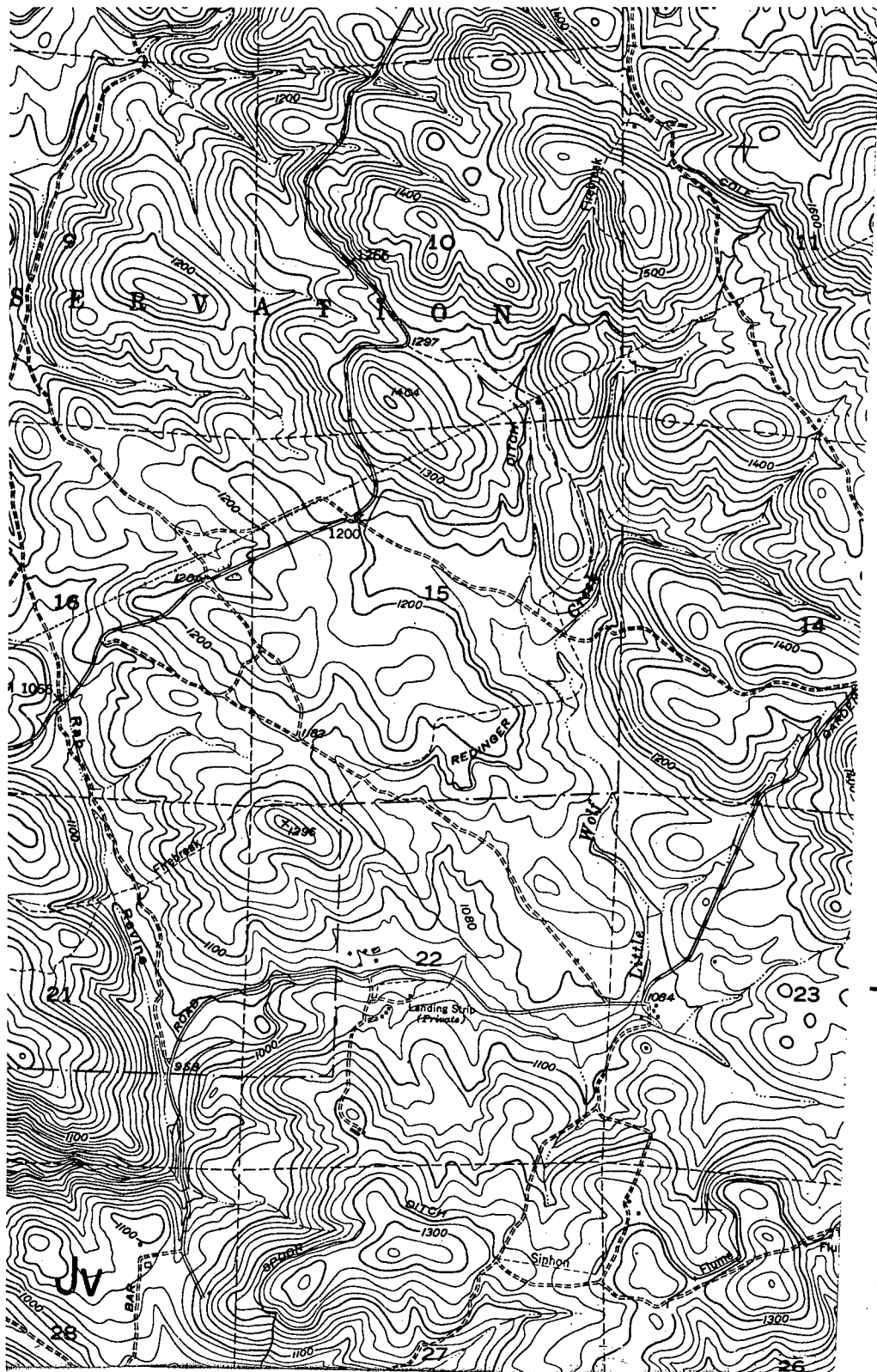


7






9




This map is a composite of quadrangles Smartville, Reddy, Camp Far West and California 7.5 minute series

ROAD CLASSIFICATION	
HARD-SURFACE ALL WEATHER ROADS	DRY WEATHER ROADS
Heavy-duty ——— <u>4 LANE 16 LANE</u>	Improved dirt ———
Medium-duty ——— <u>4 LANE 16 LANE</u>	Unimproved dirt ———
Loose-surface, graded, or narrow hard-surface ———	
U. S. Route	State Route

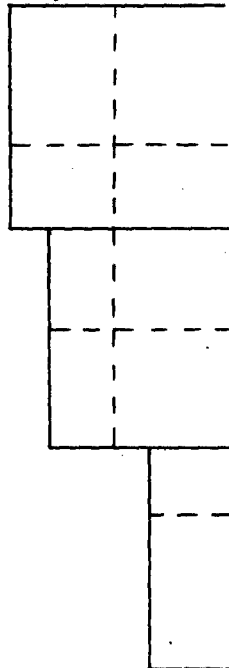
 Strike and dip of joints

 Strike and dip of dike

 Strike of vertical dike

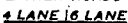

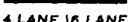


 Strike of dike

Key to sheet



This map is a composite of U.S.G.S. quadrangles Smartville, Rough and Ready, Camp Far West and Wolf, California 7.5 minute series.

ROAD CLASSIFICATION

HARD-SURFACE ALL WEATHER ROADS		DRY WEATHER ROADS	
Heavy-duty		Improved dirt	
Medium-duty		Unimproved dirt	
Loose-surface, graded, or narrow hard-surface 			



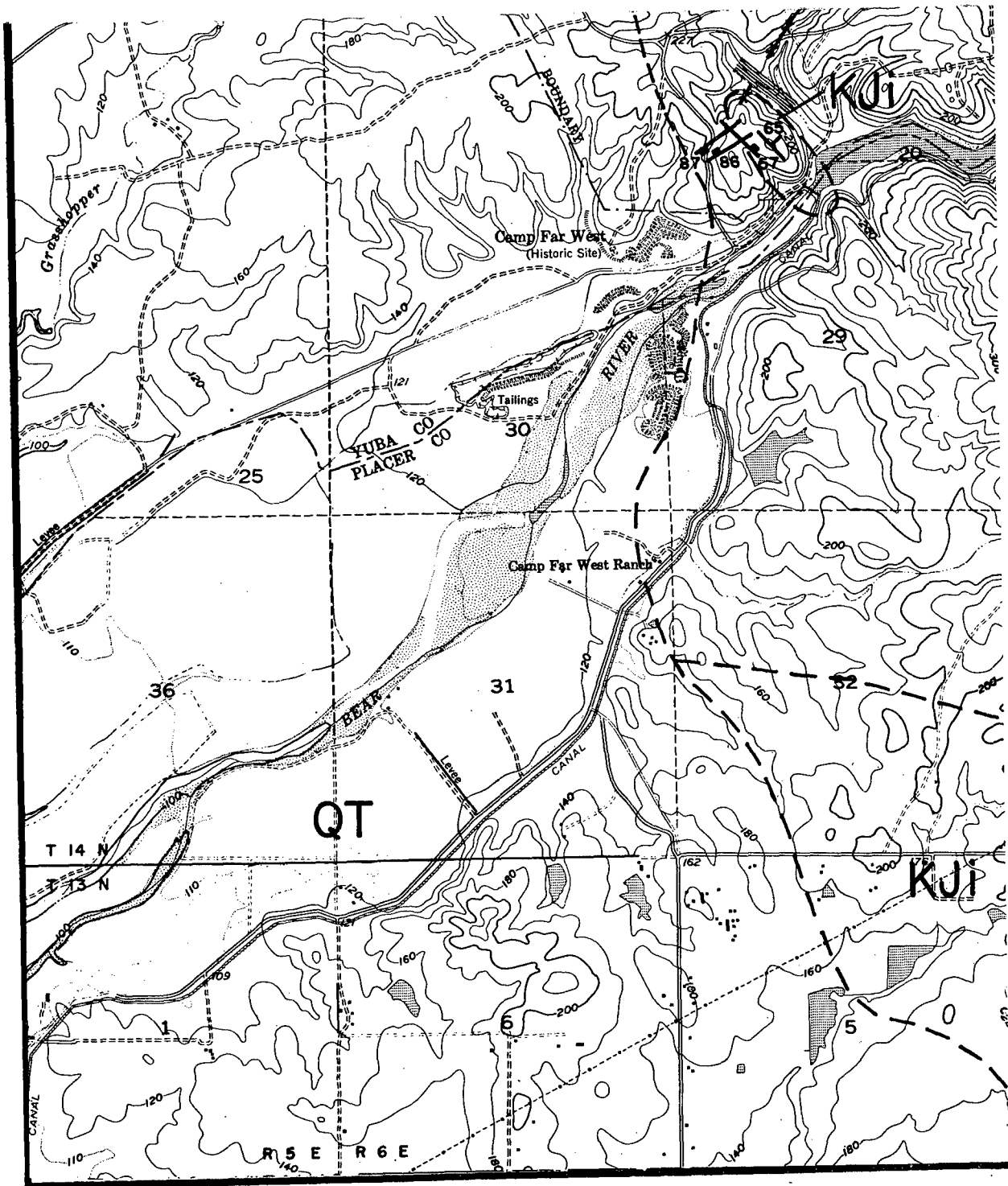
U. S. Route

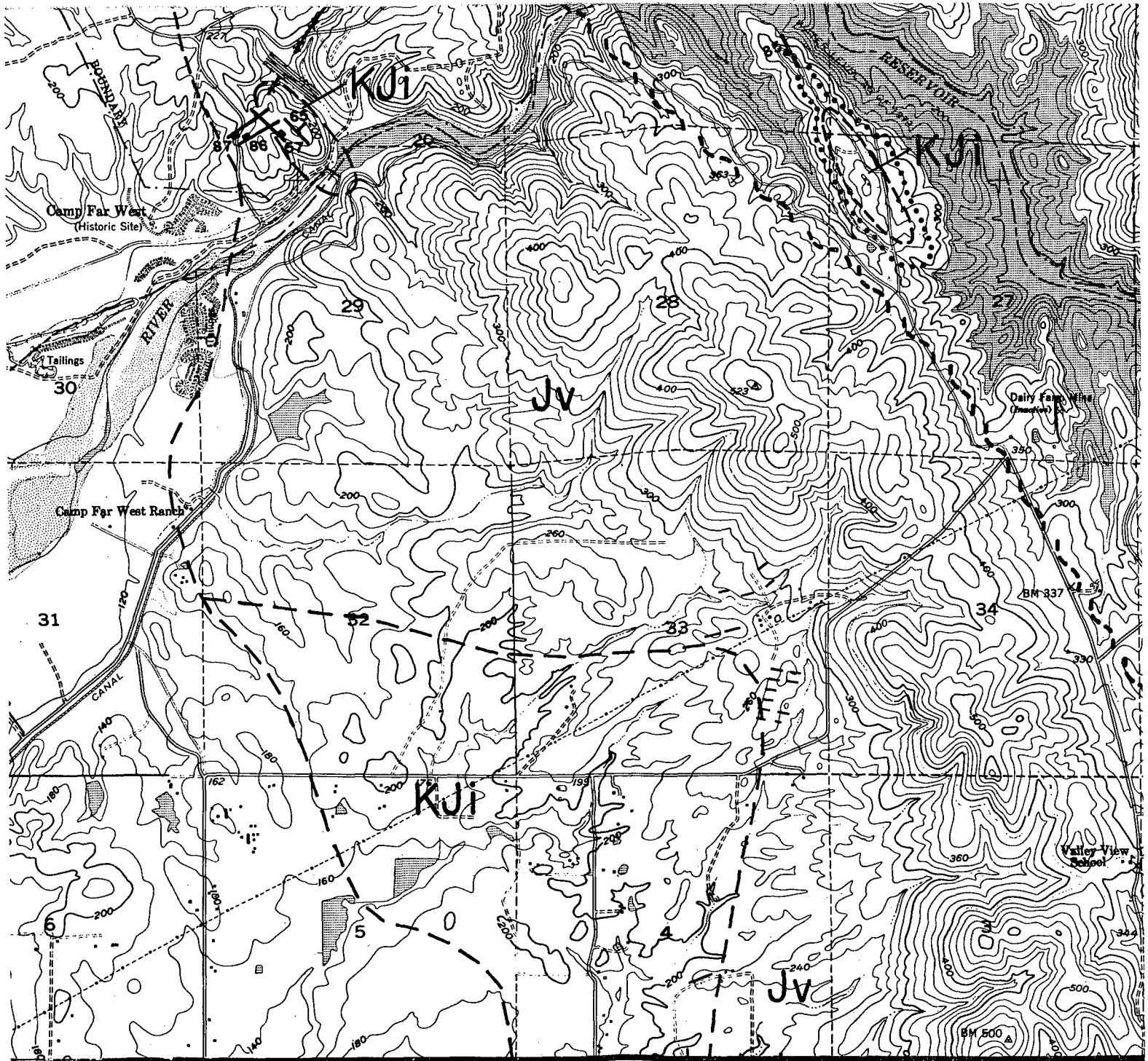


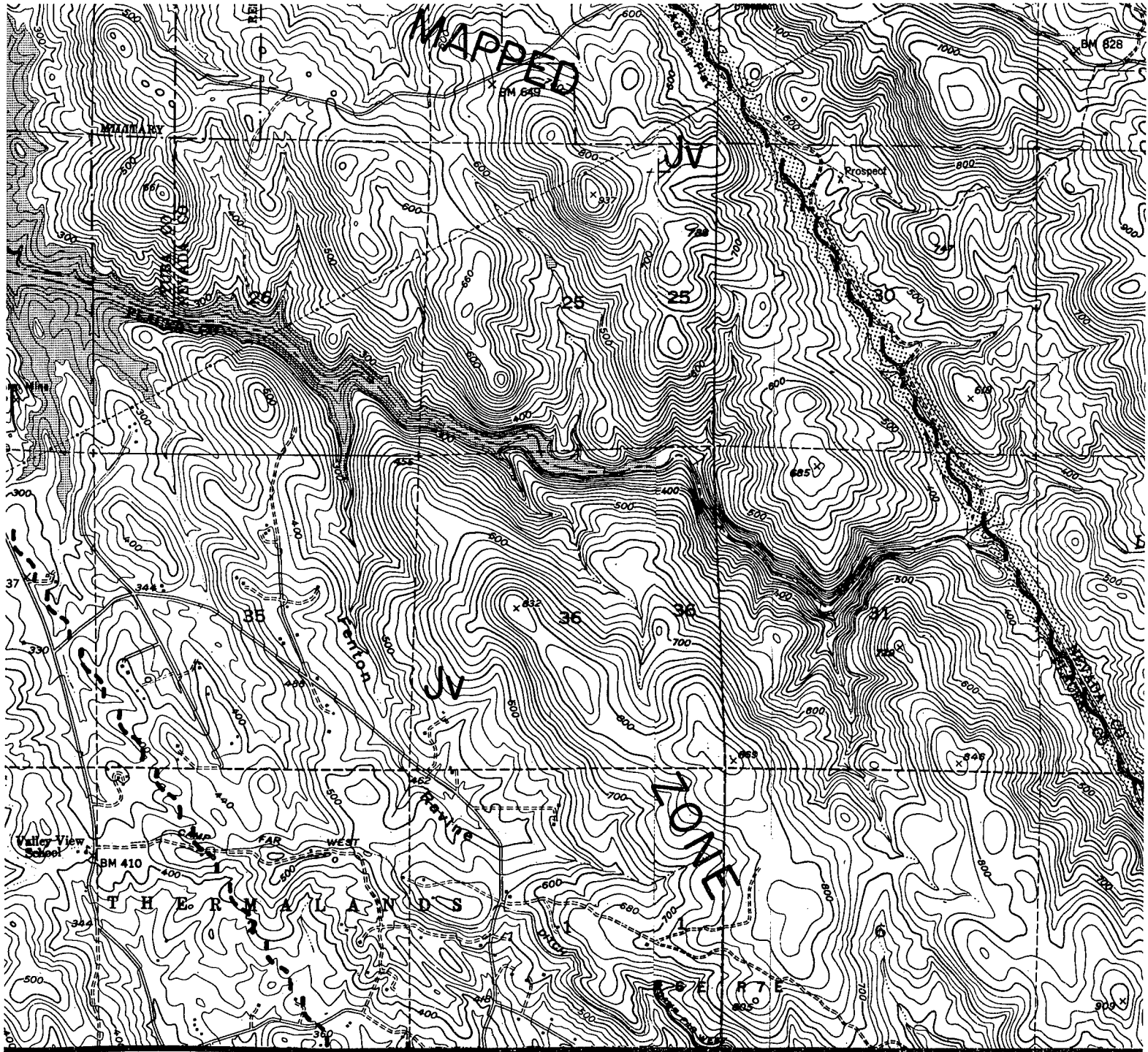
State Route



QUADRANGLE LOCATION

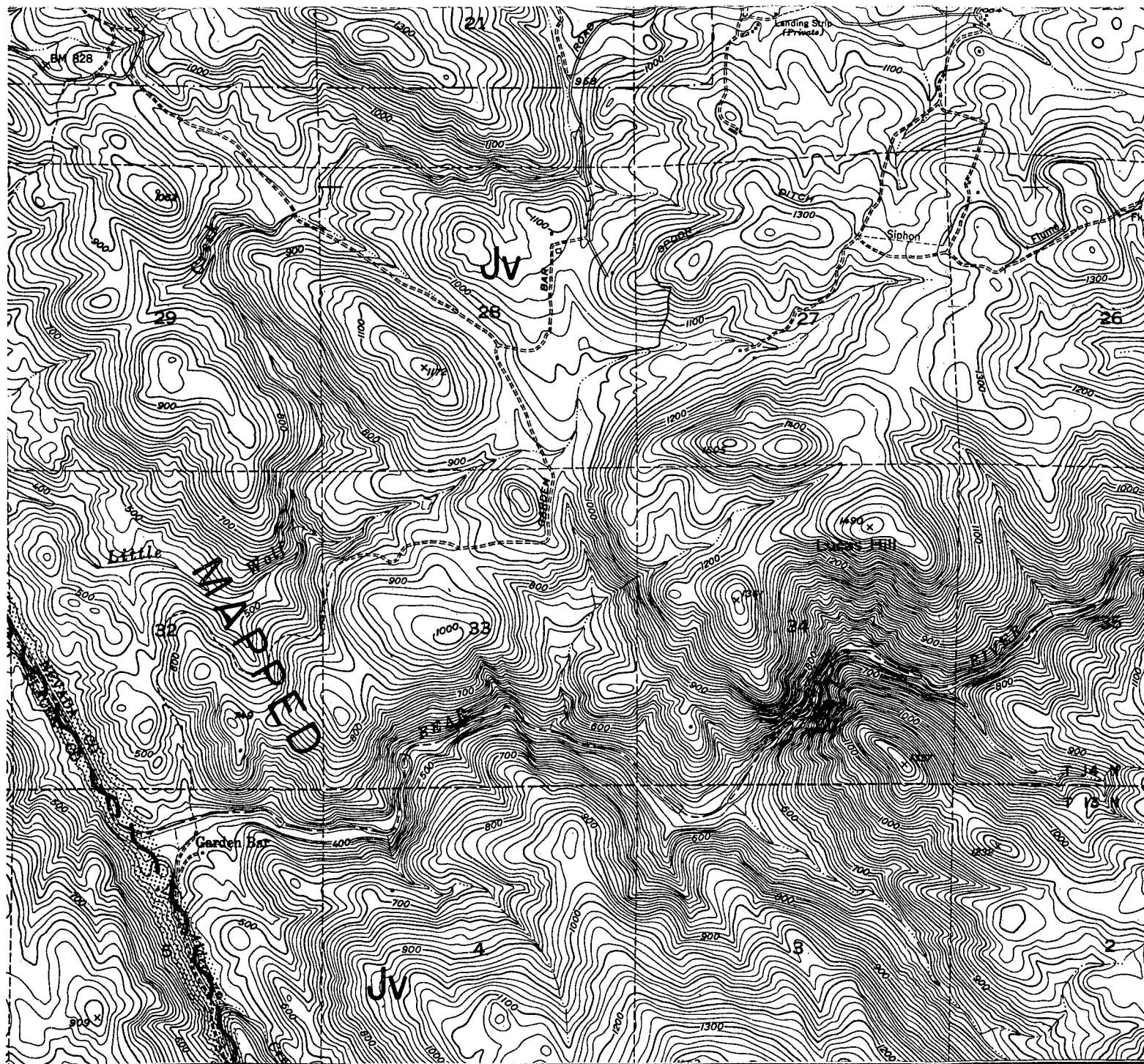






SAFETY PAYS

14



YS



15

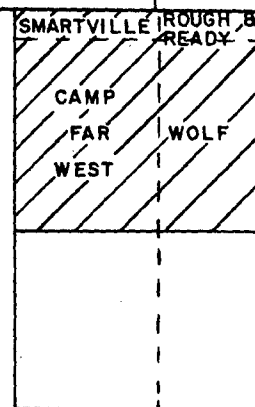
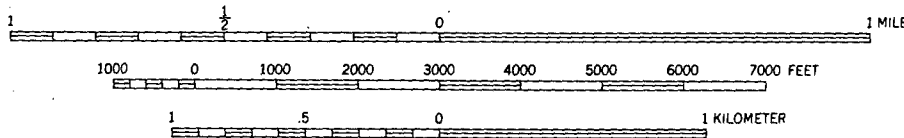
This map is a composite of U.S.G.S. quadrangles Smartville, Rough and Ready, Camp Far West and Wolf, California 7.5 minute series.

ROAD CLASSIFICATION

HARD-SURFACE ALL WEATHER ROADS DRY WEATHER ROADS
 Heavy-duty ——— 2 LANE 16 LANE Improved dirt ———
 Medium-duty ——— 2 LANE 16 LANE Unimproved dirt ———
 Loose-surface, graded, or narrow hard-surface ———
 U. S. Route State Route



SCALE 1:24000



REVISION	DATE	DESCRIPTION	BY	BY

DEPARTMENT OF THE ARMY
 SACRAMENTO DISTRICT, CORPS OF ENGINEERS
 SACRAMENTO, CALIFORNIA

DESIGNED BY:

MARYSVILLE LAKE PROJECT

DRAWN BY:

PARKS BAR ALTERNATE

CHECKED BY:

REGIONAL GEOLOGY

R. J. Anderson

FAULT EVALUATION STUDY

PREPARED BY: R. Treat, K. Buer

J. Gewerth, A. Price, J. Musto

SUBMITTED:

P. J. Guthrie

CHIEF, GEOLOGY SECTION

APPROVAL RECOMMENDED:

APPROVED:

DATE:

CHIEF, FDN&MATS BRANCH

CHIEF, ENGINEERING DIVISION

PREPARED UNDER THE DIRECTION OF

DONALD M. O'SHEI

COL., CORPS OF ENGINEERS, U. S. A.

DISTRICT ENGINEER

SCALE: AS SHOWN

SPEC. NO.

FILE NO. YU-4-20-39

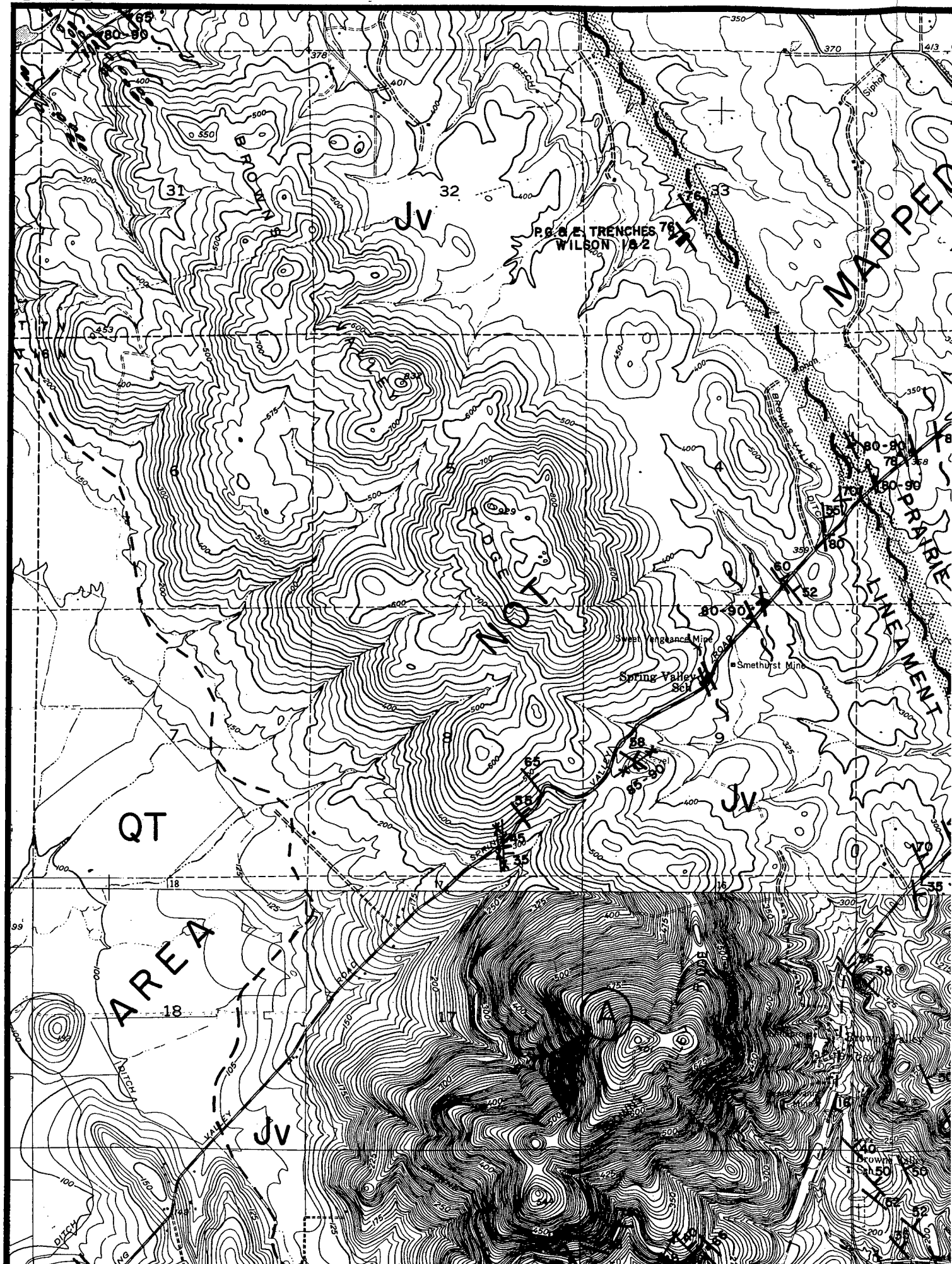
SHEETS

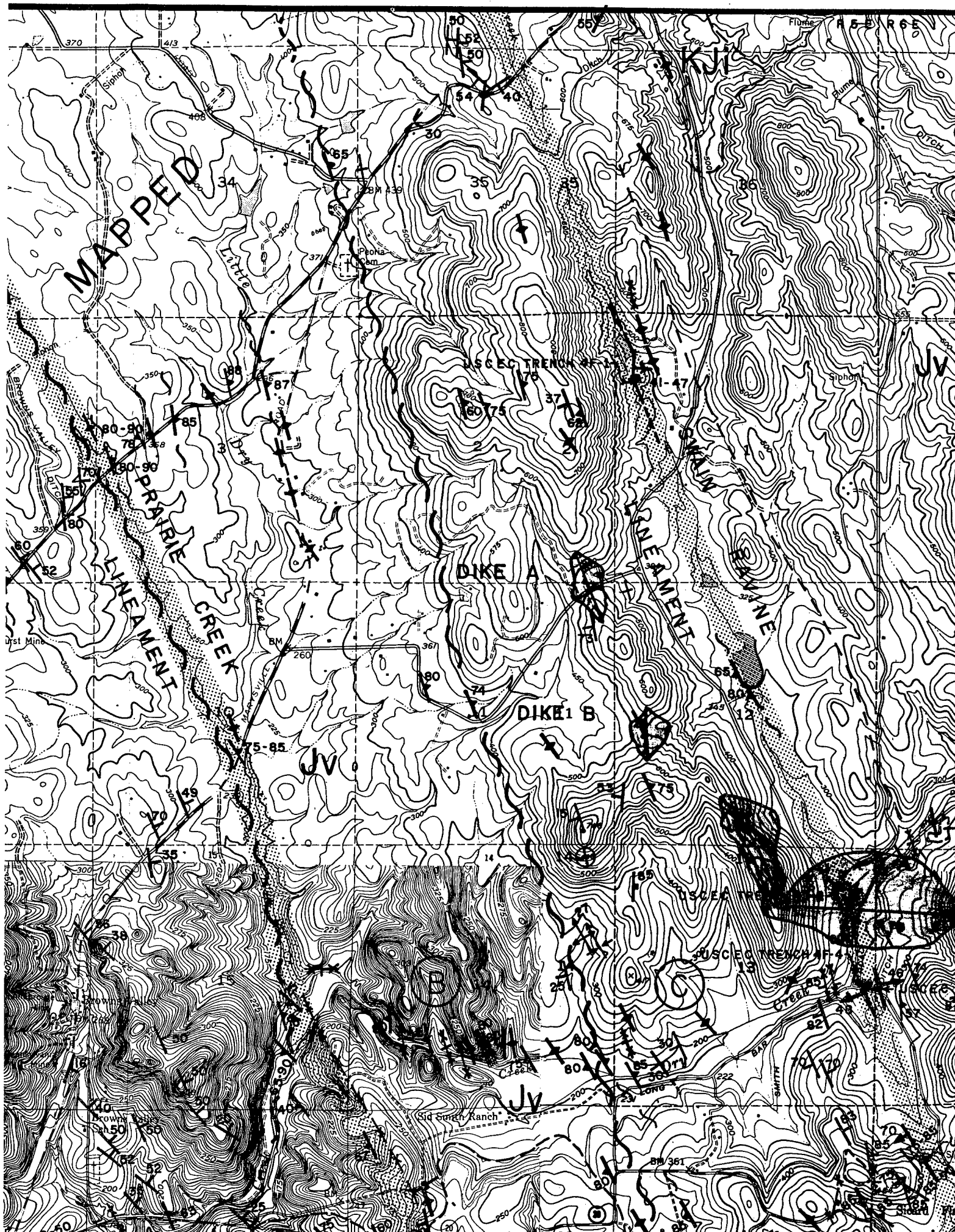
SHEET NO.

39/1 to 39/5

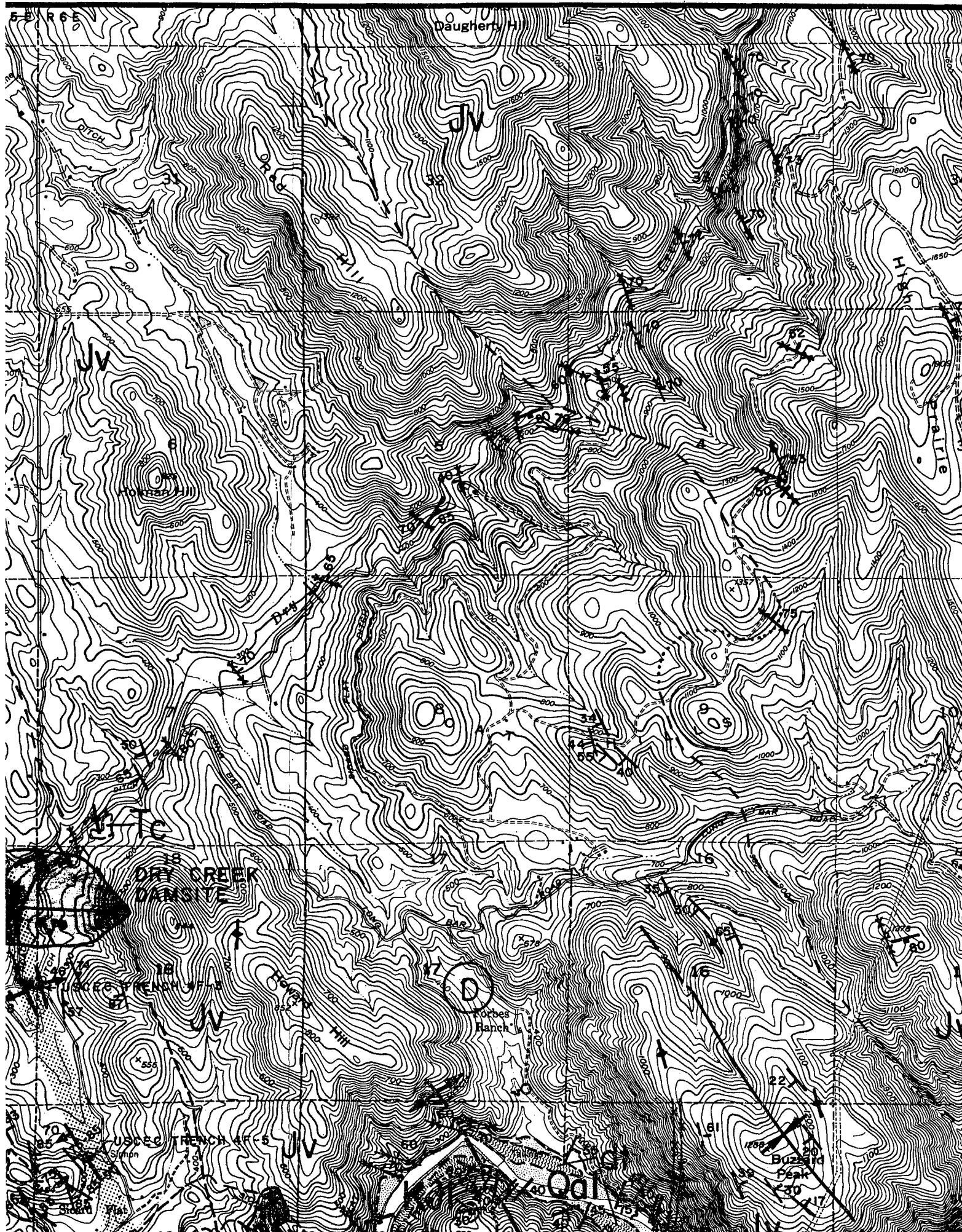
39/2

PLATE II





ALUE ENGINEERING PAYS 3



EXPL

dt	Dredge tailings.
Qal	Recent alluvium.
QT	Sedimentary and western margin o
Tc	Tertiary gravels of uncertain age
Tg	Terrace deposits the river channe
KJi	Mesozoic intrusi granite, granodi

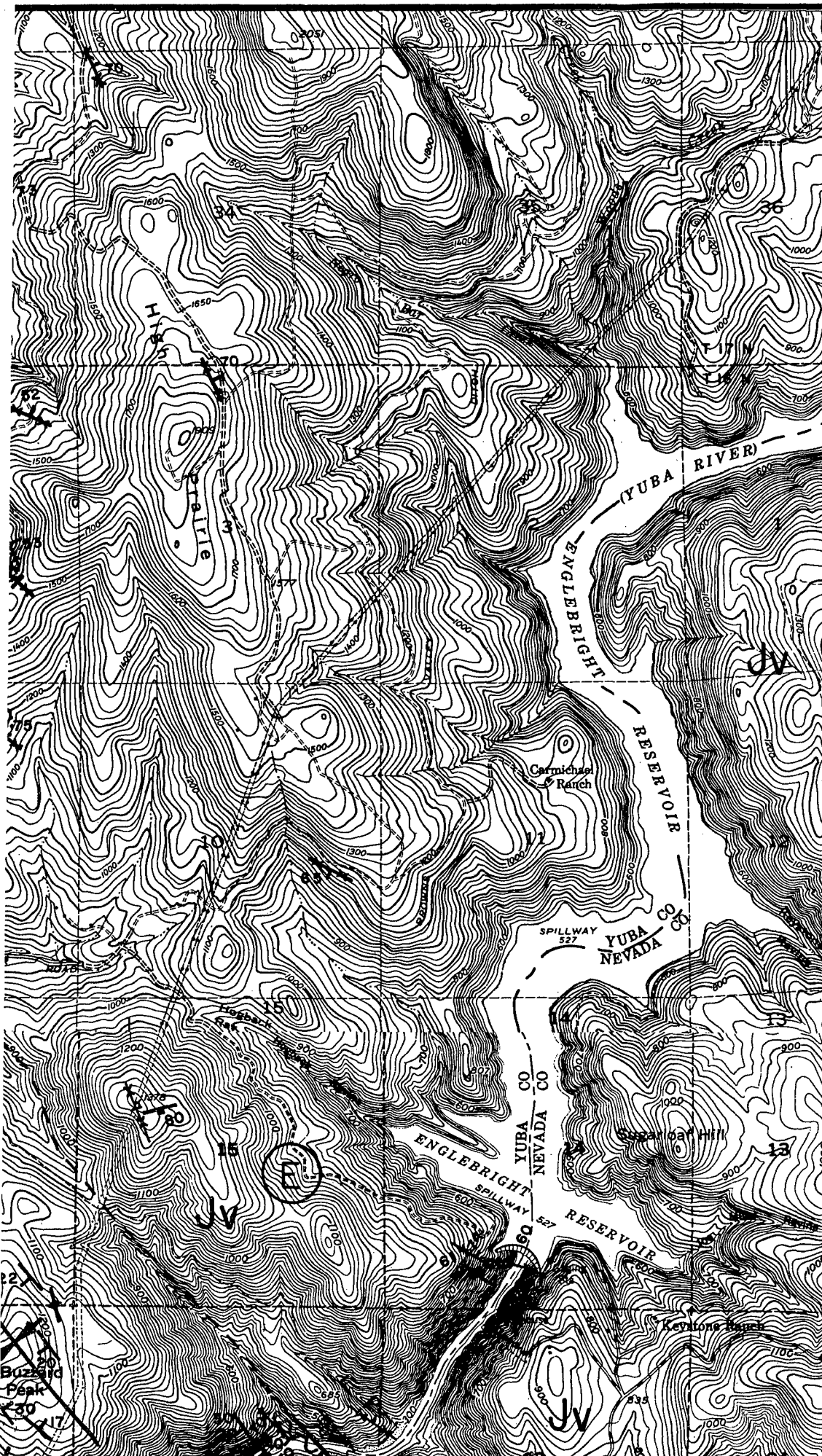
Jv	Metavolcanic roc pillowed and non and lithic tuffs dacitic dikes. in the project a
----	--

- (A) Group A cor breccias, p flows, pyroclastic dioritic di lithic tuff
- (B) Group B (st rite, clinc schist faci mafic tuffa pacted and agglomerate dikes.
- (C) Group C cor pyroclastic breccia or
- (D) Group D is Towed to ne with pillow to felsic body occur
- (E) Group E is about 70% pillowed f

The QT/Jv generalize (Burnett a used are f mapping wa NOT MAPPED

Geologic c later.

- Approximat
- ~ Regional s
- General lo



EXPLANATION OF SYMBOLS

QUATERNARY

dt	<u>Dredge tailings.</u> Sand, gravel and cobbles from gold dredging.
Qal	<u>Recent alluvium.</u> Stream channel deposits.

TERTIARY TO QUATERNARY

QT	<u>Sedimentary and volcanic deposits.</u> Undifferentiated along the western margin of map; locally overlies metavolcanic bedrock.
Tc	<u>Tertiary gravels.</u> Auriferous and non-auriferous gravel deposits of uncertain age; locally includes volcanic pyroclastic rocks.
Tg	<u>Terrace deposits.</u> Gravel deposits of uncertain age adjacent to the river channel; locally overlies the Eocene Lone Formation.

JURASSIC TO CRETACEOUS

KJi	<u>Mesozoic intrusive igneous rocks.</u> Includes variations of granite, granodiorite, tonalite, gabbro, diorite, and quartz.
-----	---

UPPER JURASSIC

Jv	<u>Metavolcanic rocks.</u> Chiefly metamorphosed basaltic to andesitic, pillowed and non-pillowed flows and pyroclastics including crystal and lithic tuffs, tuff breccias or agglomerates with diabasic to dacitic dikes. Five groups of metavolcanic rocks are described in the project area.
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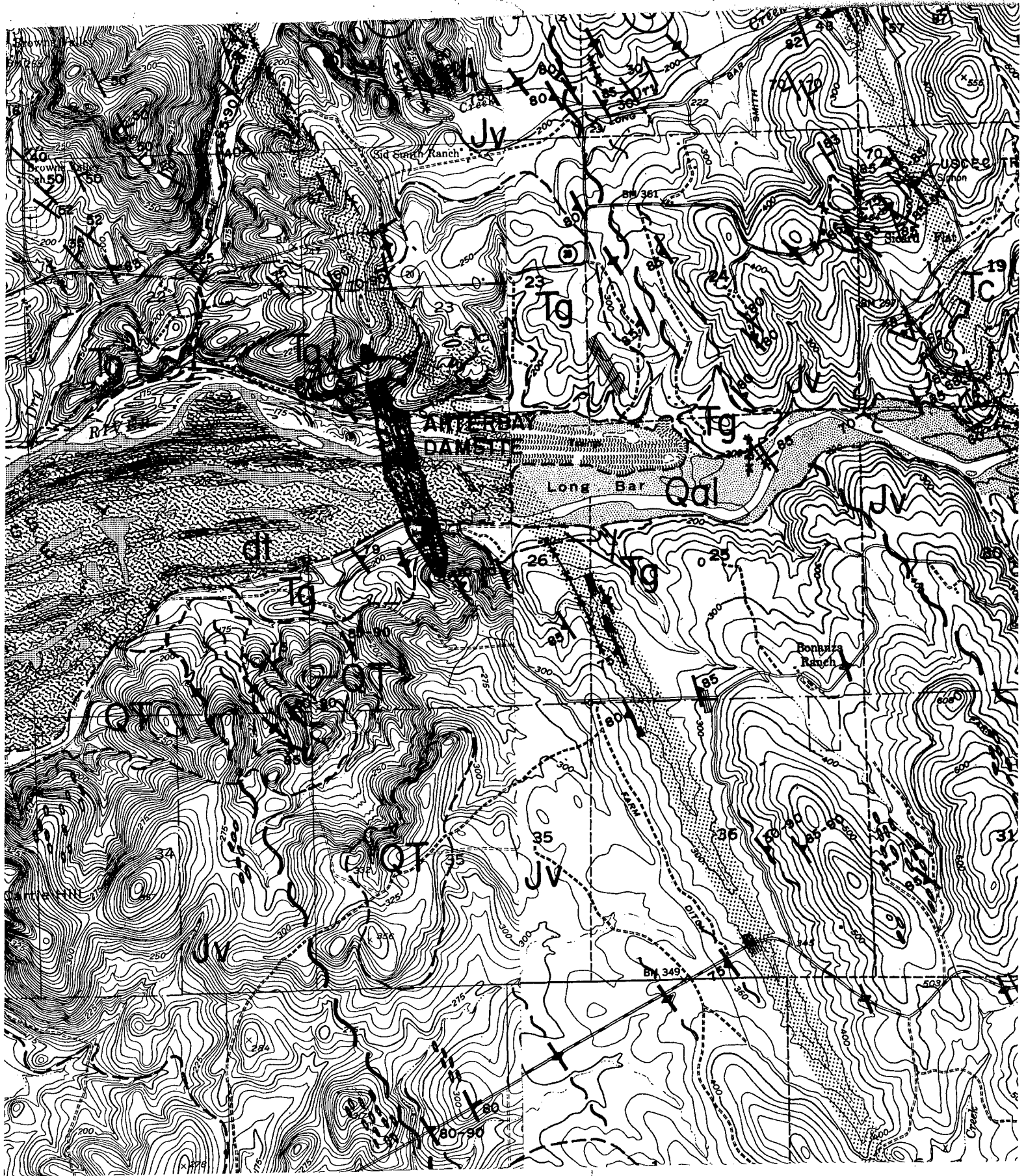
- (A) Group A consists of interlayered pyroxene andesite tuff breccias, phryic to non-phryic, pillowed to non-pillowed flows, pyroxene pumice tuff breccia with basaltic to quartz dioritic dikes, finely laminated pyroclastic crystal and lithic tuffs and pyroxene tuff breccia.
- (B) Group B (shear zone) primarily consists of actinolite, chlorite, clinozoisite, epidote, quartz, calcite schist (green-schist facies) derived from dynamothermally metamorphosed mafic tuffaceous debris, pillowed to non-pillowed flows, compacted and devitrified rhyolitic tuffs and tuff breccia or agglomerate, intruded by pyroxene porphyritic and diabasic dikes.
- (C) Group C consists of pillowed basaltic flows, flow breccia, pyroclastic layered crystal and lithic tuffs and tuff breccia or agglomerate.
- (D) Group D is a thick sequence of basaltic to andesitic, pillowed to non-pillowed flows and flow breccias intercalated with pillow breccias and layered tuffs cut by many diabasic to felsic dikes. A gabbro diorite to quartz diorite igneous body occurs inside Timbuctoo Bend.
- (E) Group E is essentially a sheeted dike complex consisting of about 70% basaltic to felsic dikes which have intruded pillowed flows, flow breccias and tuffs.

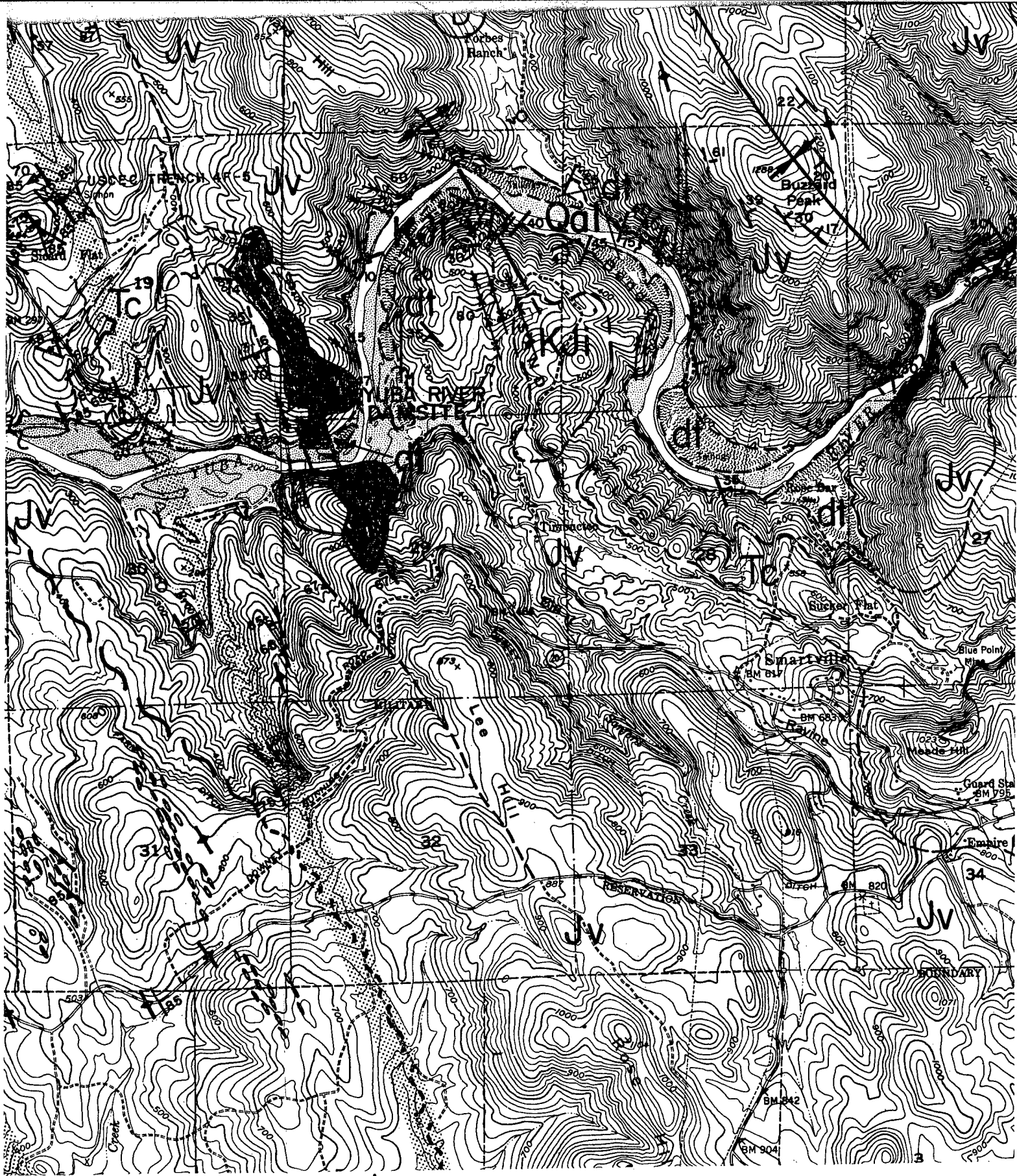
NOTES

The QT/Jv contact along the western side of the map is generalized from the Geologic Map of California, Chico Sheet (Burnett and Jennings, 1962). Most of the geologic symbols used are from Clark, 1976. Only reconnaissance geological mapping was done in some areas which are designated "AREA NOT MAPPED."

Geologic contacts between Groups A to E will be extended later.

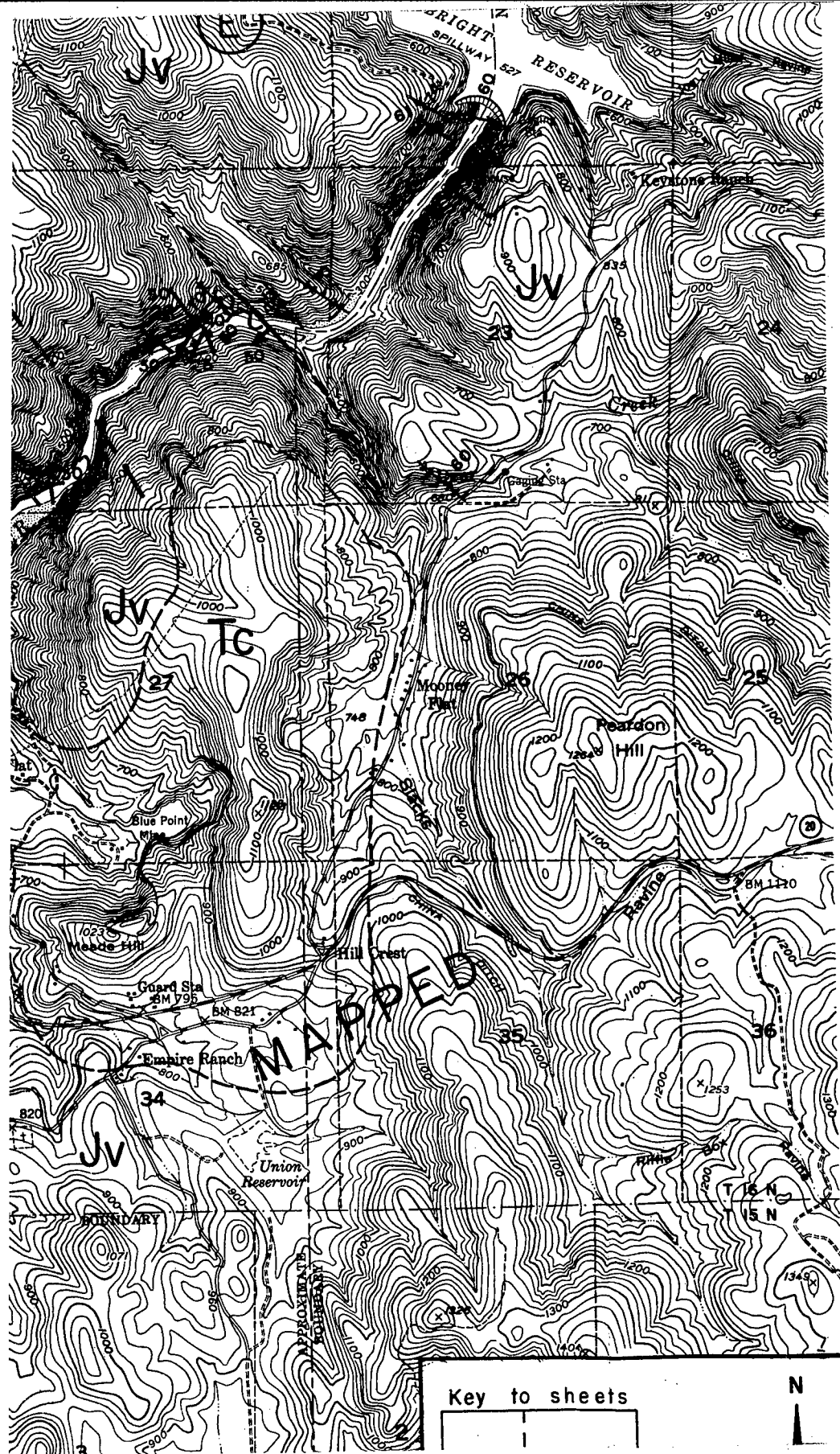
- Approximate geologic contact
- ~~~~~ Regional shear zone boundary; inferred
- ▨ General location of lineament





generalized from t
(Burnett and Jenni
used are from Clar
mapping was done i
NOT MAPPED."

Geologic contacts
later.



- Approximate geolog
- ~ Regional shear zor
- General location c
- Generalized tombst
- 27 Syncline showing t
- 27 Anticline showing
- Generalized strike
- Strike and dip of
- Strike of vertica
- Strike and dip of
- Strike and dip of
- Strike and dip of
- Strike and dip of
- Strike and dip of
- Altered rock zone
- Spring

Key to sheets

N

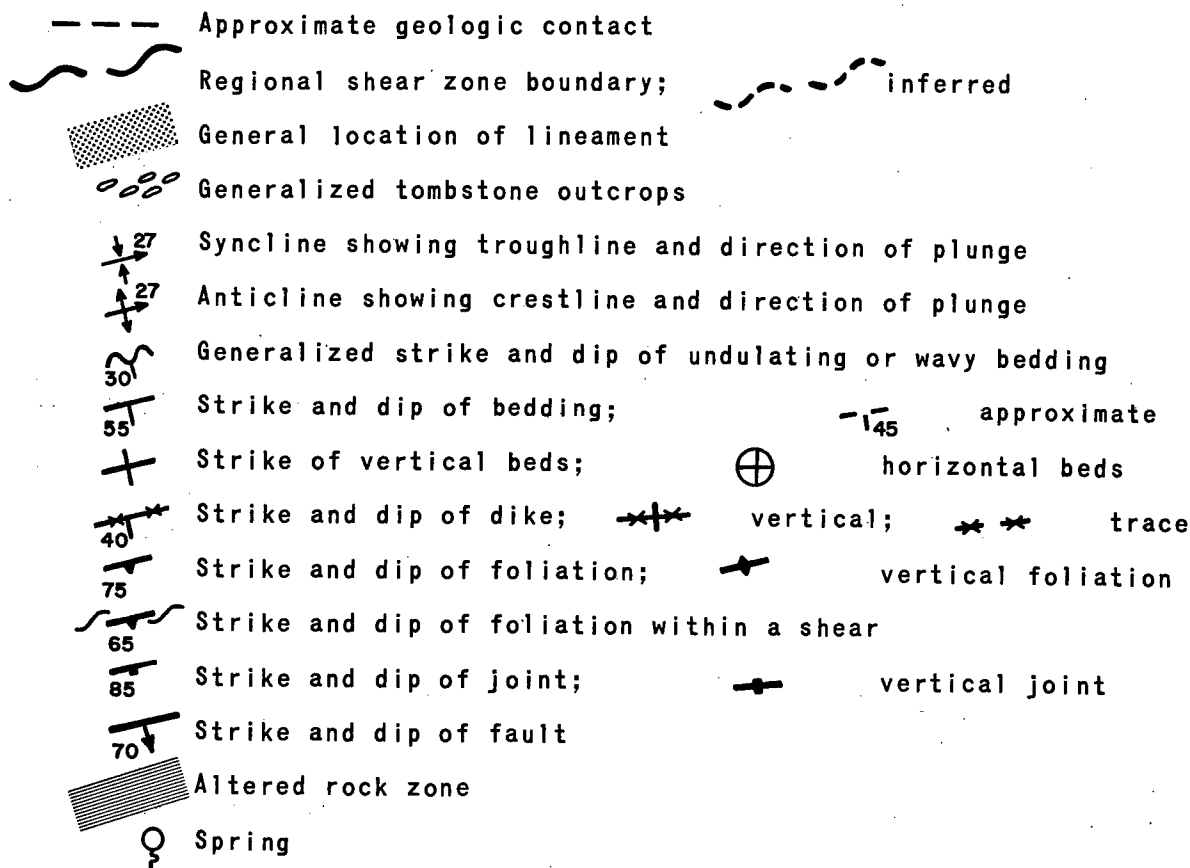
ROAD CLASSIFICATION

- Primary highway, hard surface
- Light-duty road, hard o improved surface
- Secondary highway, hard surface
- Unimproved road

9

The 41/51 contact along the western side of the map is generalized from the Geologic Map of California, Chico Sheet (Burnett and Jennings, 1962). Most of the geologic symbols used are from Clark, 1976. Only reconnaissance geological mapping was done in some areas which are designated "AREA NOT MAPPED."

Geologic contacts between Groups A to E will be extended later.



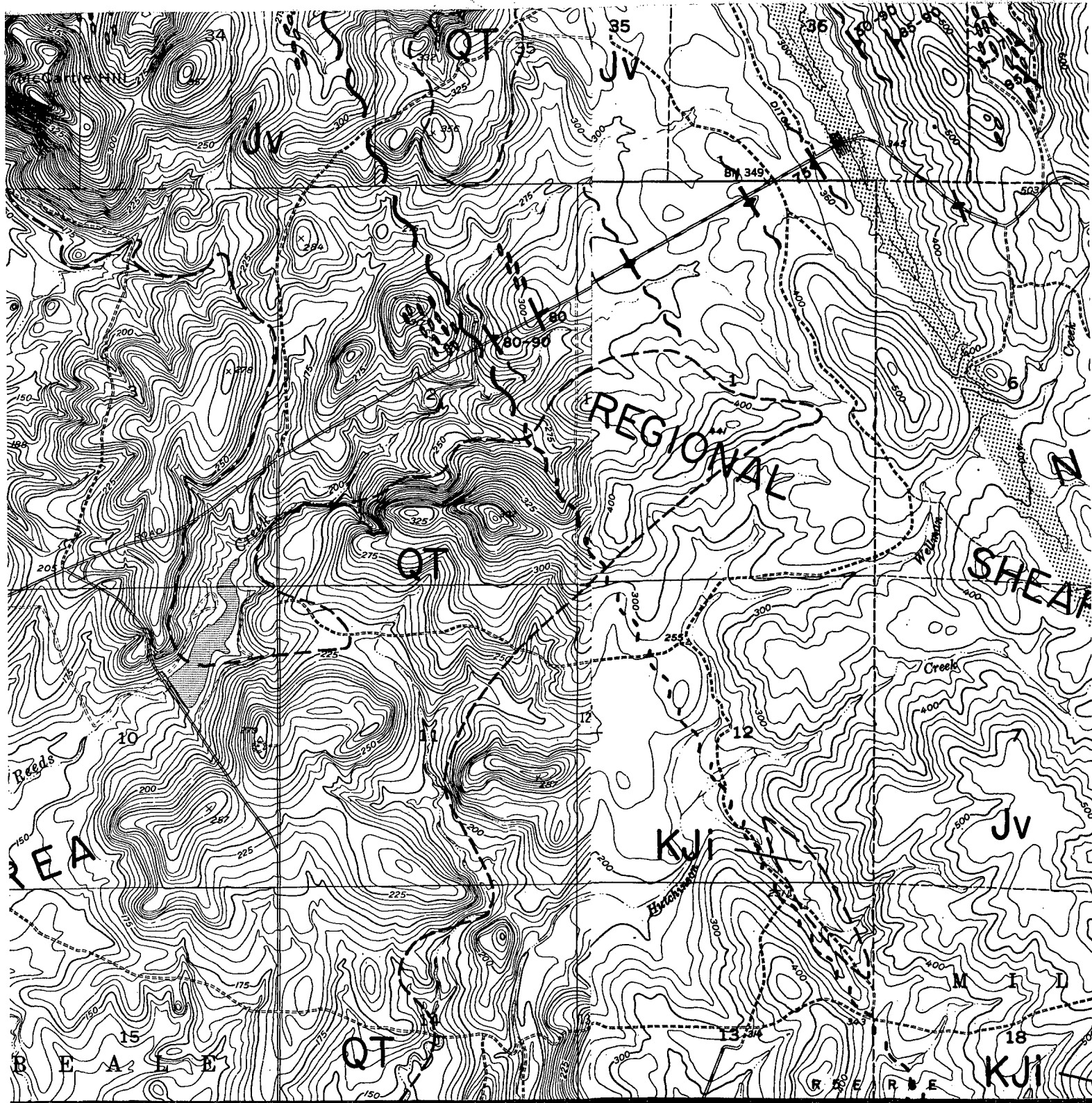
ROAD CLASSIFICATION

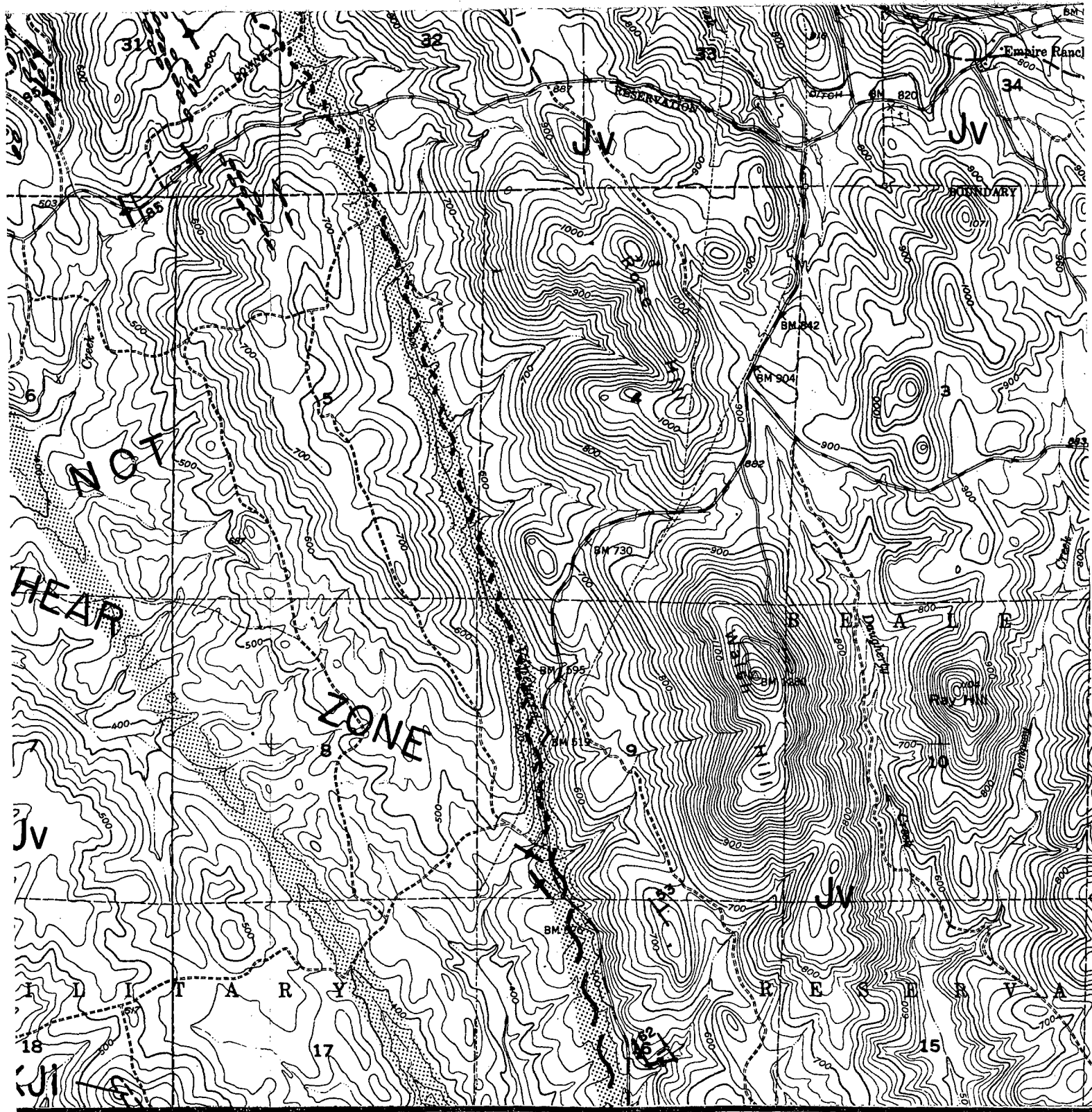
Primary highway, hard surface	Light-duty road, hard or improved surface
Secondary highway, hard surface	Unimproved road

NOTE:

This map is a composite of USGS quadrangles Loma Rica, Oregon House, Browns Valley and Smartville, California 7.5 minute series.

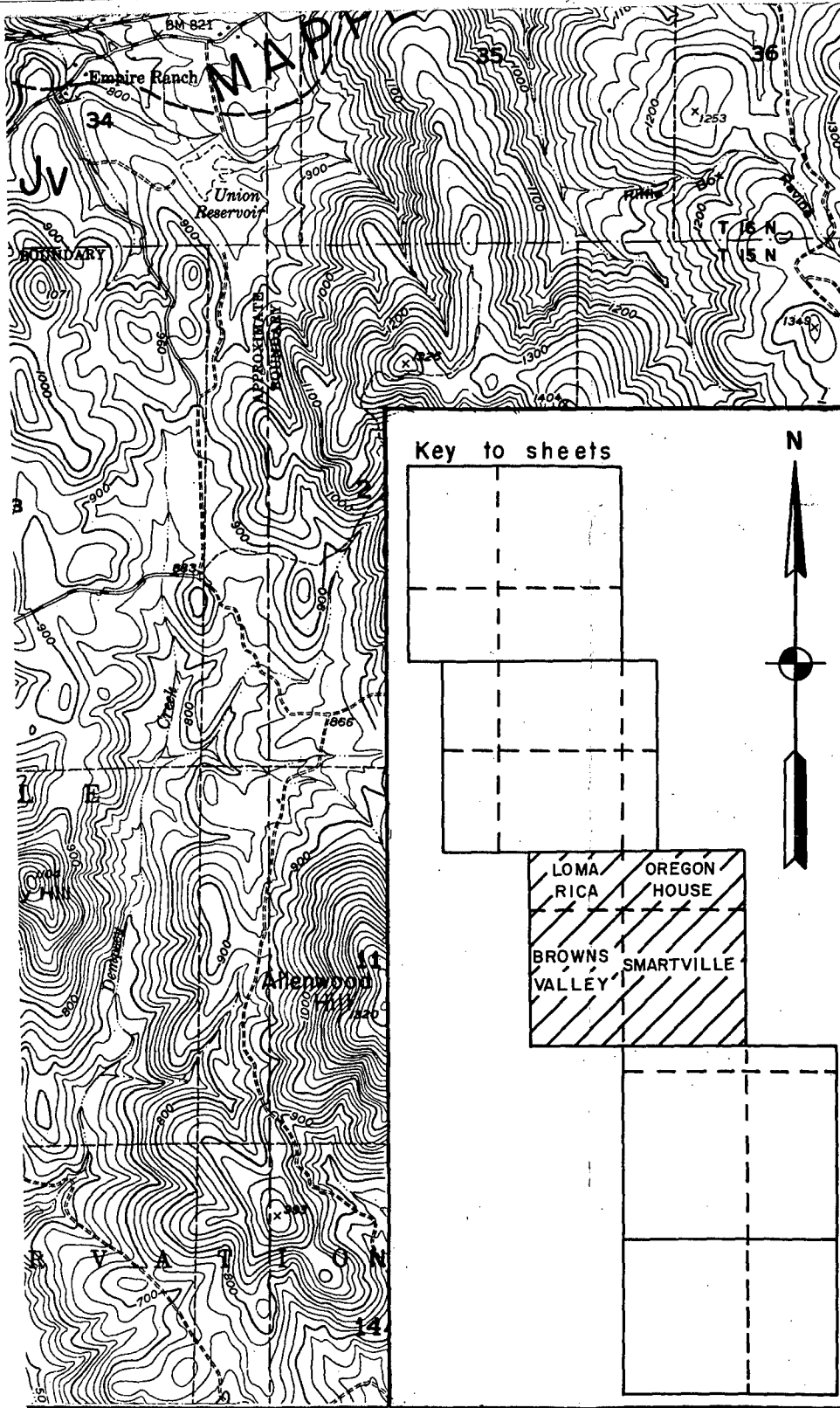






SAFETY PAYS

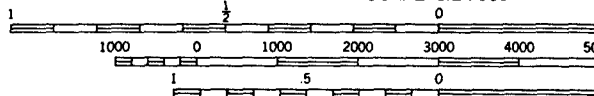




ROAD CLASSIFICATION

Primary highway, hard surface Light-duty road, hard or improved surface
 Secondary highway, hard surface Unimproved road
 Interstate Route U. S. Route State Route

SCALE 1:24,000





DESIGNED BY:		RE FAULT
DRAWN BY: <i>D. W. Paige</i>		
CHECKED BY: <i>R. J. Anderson</i>		
PREPARED BY: <i>R. Treat, K. Buer, J. Gewerth, A. Price, J. Musto</i>		
SUBMITTED: <i>P. A. Guthrie</i> CHIEF, GEOLOGY SECTION		
APPROVAL RECOMMENDED: <i>J. Sciarandone</i> CHIEF, FDNS. & MAT'L S. BRANCH		APPROVED: <i>P. A. Guthrie</i> CHIEF, I
PREPARED UNDER THE DIRECTION OF DONALD M. O'SHEI COL., CORPS OF ENGINEERS, U. S. A. DISTRICT		

NOTE:

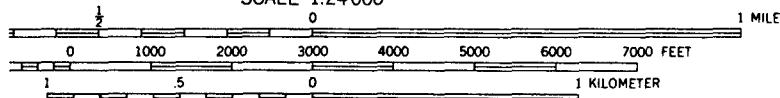
This map is a composite of USGS quadrangles Loma Rica, Oregon House, Browns Valley and Smartville, California 7.5 minute series.

ROAD CLASSIFICATION

Highway, _____ Light-duty road, hard or improved surface _____
 Highway, _____ Unimproved road _____
 State Route  U. S. Route  State Route



SCALE 1:24 000



DATE	DESCRIPTION	BY	BY

DEPARTMENT OF THE ARMY
 SACRAMENTO DISTRICT, CORPS OF ENGINEERS
 SACRAMENTO, CALIFORNIA

MARYSVILLE LAKE PROJECT
 PARKS BAR ALTERNATE
 REGIONAL GEOLOGY
 FAULT EVALUATION STUDY

Person
 R. Treat, K. Buer
 Price, J. Musto

W. H. H. H.
 GEOLOGY SECTION

RECOMMENDED:
W. H. H. H.
 IS & MATL'S BRANCH

APPROVED:
R. G. W. S.
 CHIEF, ENGINEERING DIVISION

DATE: _____

UNDER THE DIRECTION OF

W. L. M. O'SHEI

OF ENGINEERS, U. S. A.

DISTRICT ENGINEER

SCALE: AS SHOWN SPEC. NO.

FILE NO. YU-4-20-39

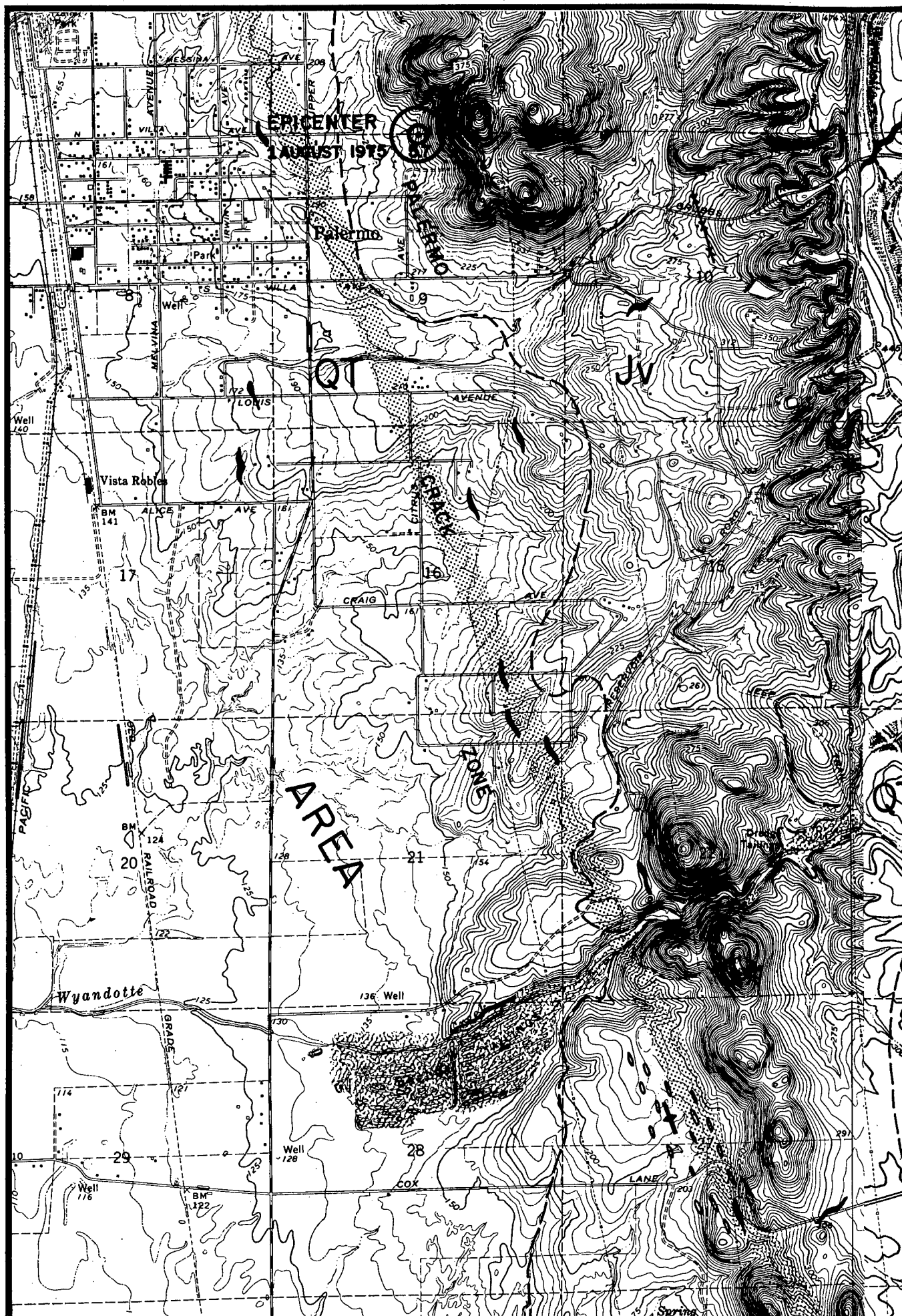
SHEETS SHEET NO.

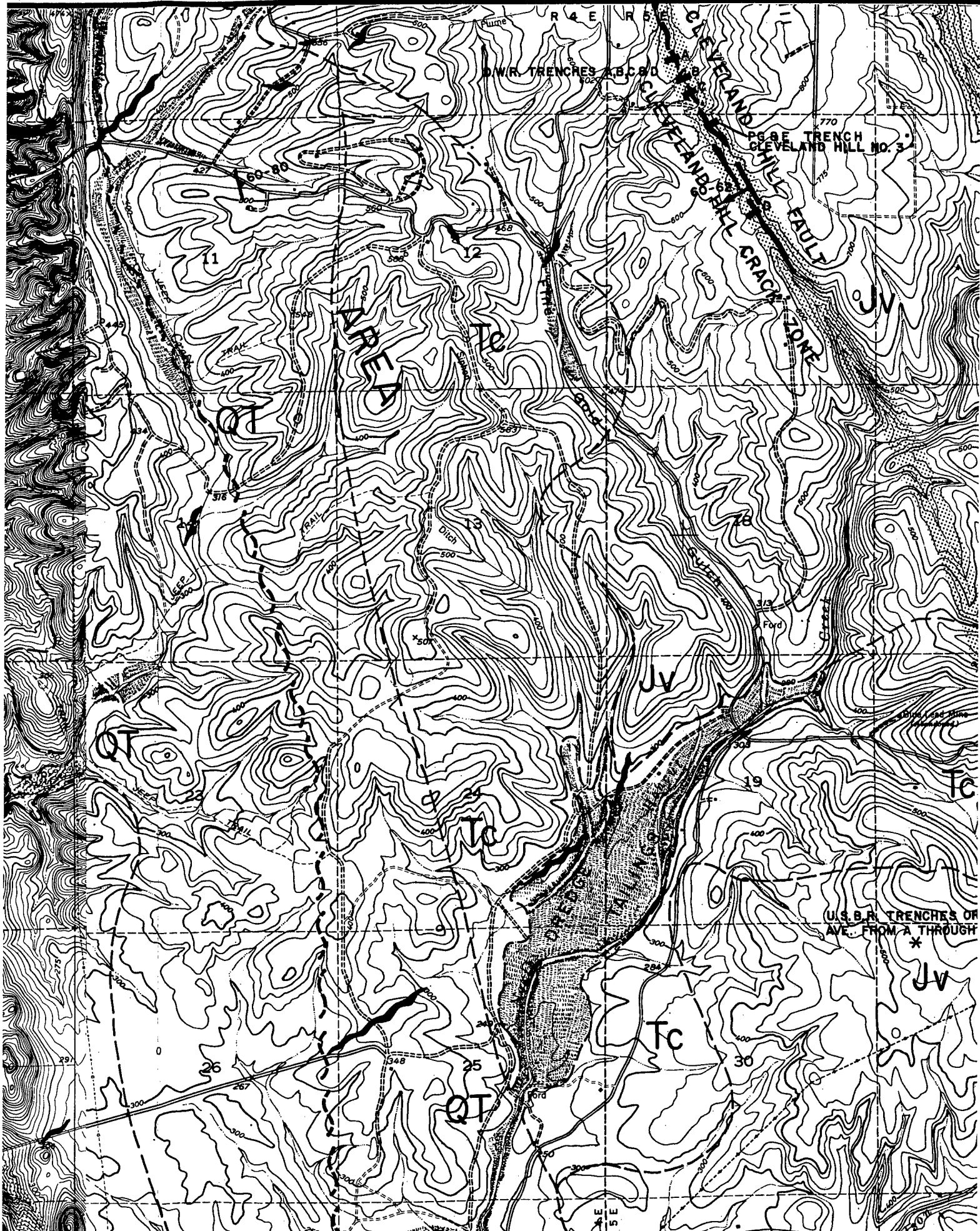
39/1 to 39/5

39/3

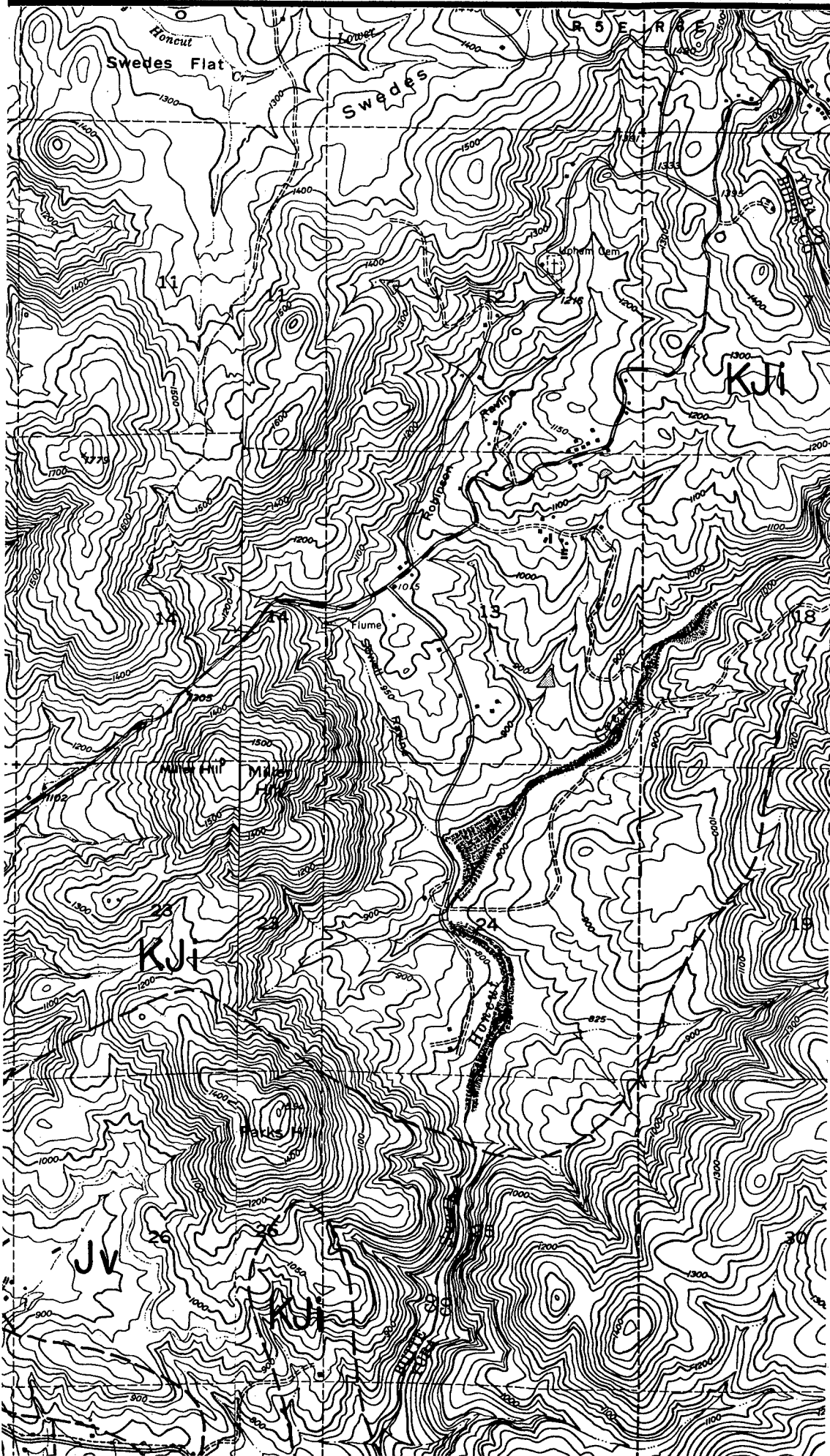
PLATE III

15





[illegible]



- QT Sedimentary and western margin o
- Tc Tertiary gravels of uncertain age
- KJi Mesozoic intrusi granodiorite, to
- Jv Metavolcanic roc pillowed and non crystal and lith diabasic to daci are described in

Geologic contact California, Chic symbols used are geological mappi "AREA NOT MAPPED"

The Paynes Peak House but its lo

*The location of vicinity of the

- Approximate
- Regional sh
- General loc
- 155 Strike and
- 78 Strike and
- 40 Strike and
- 75 Strike and
- 65 Strike and
- 85 Strike and
- 70 Strike and
- Altered roc
- Location an the 1 August shocks (She
- Sheared roc

EXPLANATION OF SYMBOLS

TERTIARY TO QUATERNARY

- QT** Sedimentary and volcanic deposits. Undifferentiated along the western margin of map; locally overlies metavolcanic bedrock.
- Tc** Tertiary gravels. Auriferous and non-auriferous gravel deposits of uncertain age; locally includes volcanic pyroclastic rocks.

JURASSIC TO CRETACEOUS

- KJi** Mesozoic intrusive igneous rocks. Includes variations of granite, granodiorite, tonalite, gabbro, diorite, and quartz.

UPPER JURASSIC

- Jv** Metavolcanic rocks. Chiefly metamorphosed basaltic to andesitic, pillowed and non-pillowed flows and pyroclastics including crystal and lithic tuffs, tuff breccias or agglomerates with diabasic to dacitic dikes. Five groups of metavolcanic rocks are described in the project area (Plate III).

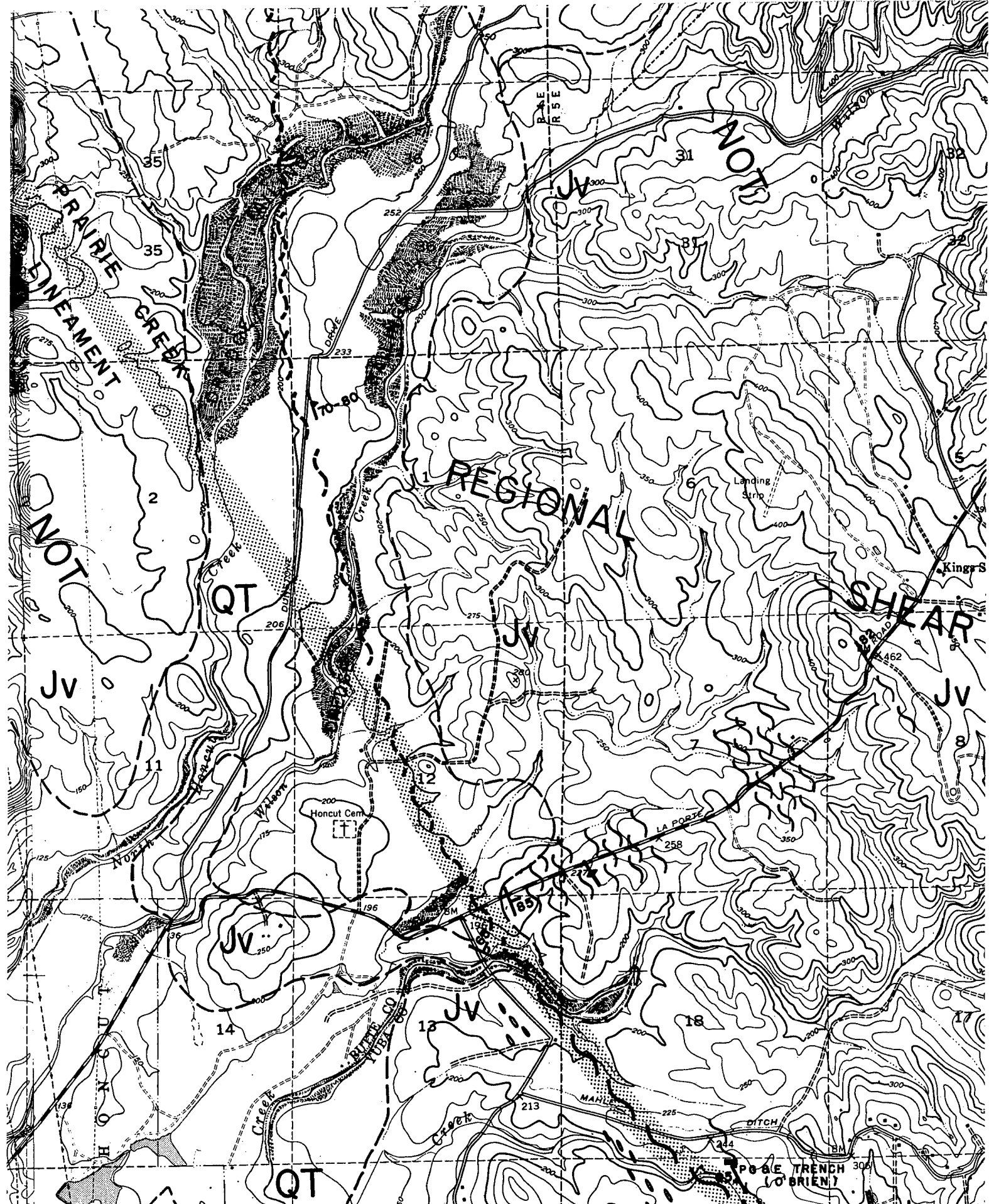
NOTES

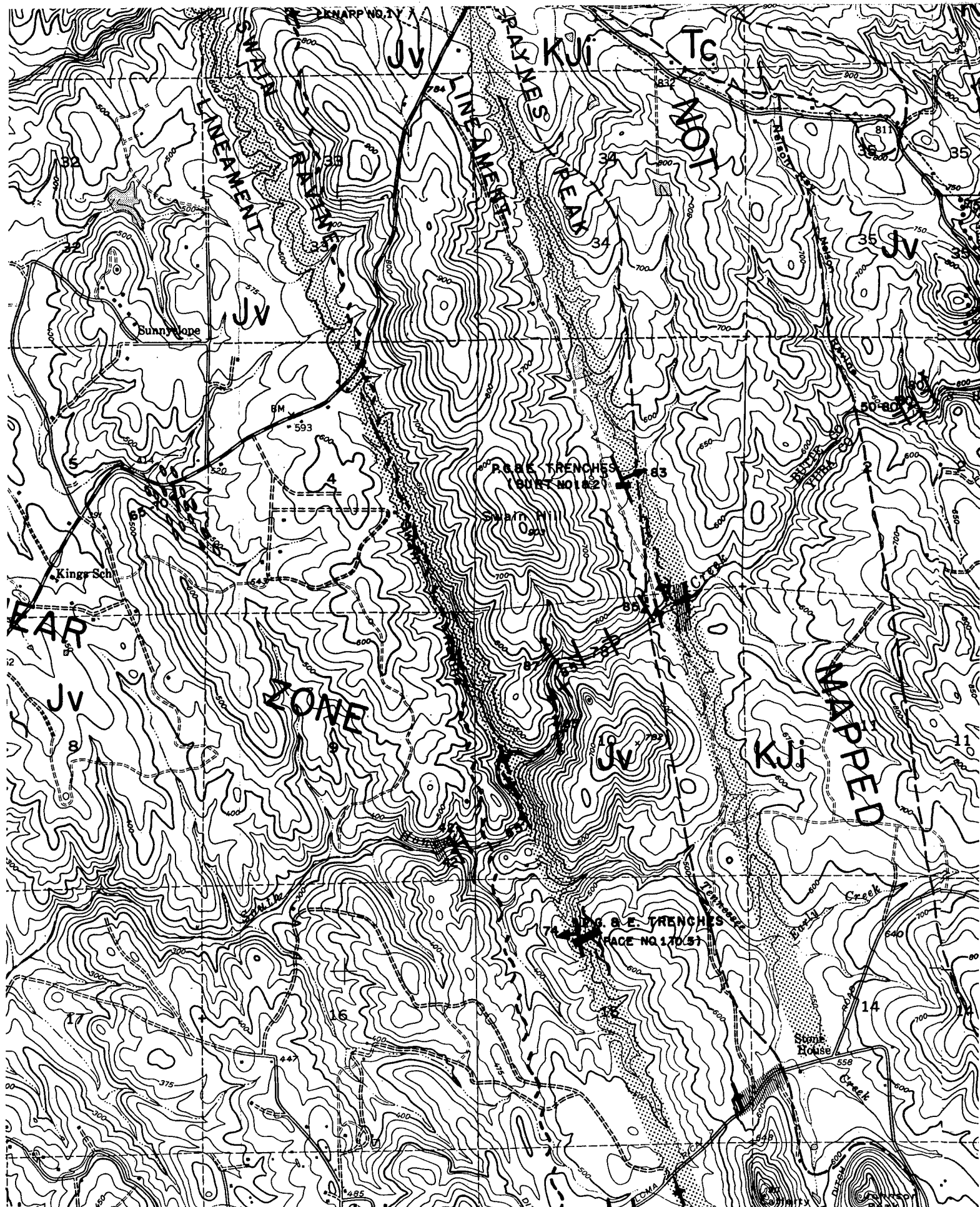
Geologic contacts are generalized from the Geologic Map of California, Chico Sheet (Burnett and Jennings, 1962). Geologic symbols used are from Clark, 1976. Only reconnaissance geological mapping was done in some areas which are designated "AREA NOT MAPPED"

The Paynes Peak lineament continues southeastward from Stone House but its location was not traced out in the field.

*The location of U.S.B.R. "Orange Avenue" trenches E to H, in the vicinity of the circle, is not available at this time.

- Approximate geologic contact
- ~~~~~ Regional shear zone boundary; inferred
- ▨ General location of lineament
- $\overline{T_{55}}$ Strike and dip of bedding
- $\overline{78 \curvearrowright}$ Strike and dip of overturned beds
- $\overline{\times \times 40}$ Strike and dip of dike
- $\overline{75}$ Strike and dip of foliation; \rightarrow vertical foliation
- $\overline{65}$ Strike and dip of foliation within a shear
- $\overline{85}$ Strike and dip of joint; \rightarrow vertical joint
- $\overline{70 \downarrow}$ Strike and dip of fault
- ▨ Altered rock zone
- Location and orientation of ground cracks associated with the 1 August 1975 Oroville earthquake and subsequent after-shocks (Sherburne and Hauge, 1975)
- ~~~~~ Sheared rock zone







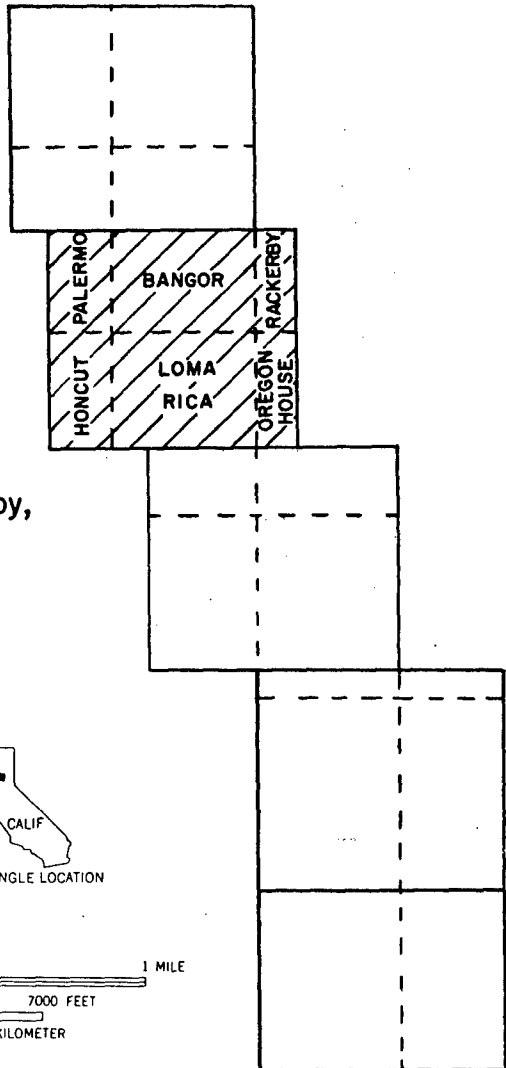
Location and orientation of ground cracks associated with the 1 August 1975 Oroville earthquake and subsequent after-shocks (Sherburne and Hauge, 1975)

Sheared rock zone

Area of abundant dikes

Generalized tombstone outcrops

Key to sheets



NOTE:

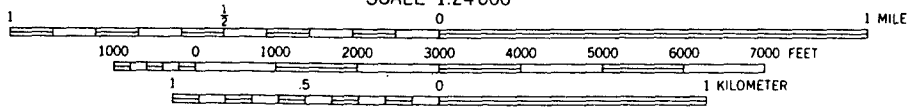
This map is a composite of U.S.G.S. quadrangles Palermo, Bangor, Rackerby, Loma Rica, Honcut and Oregon House, California 7.5 minute series.

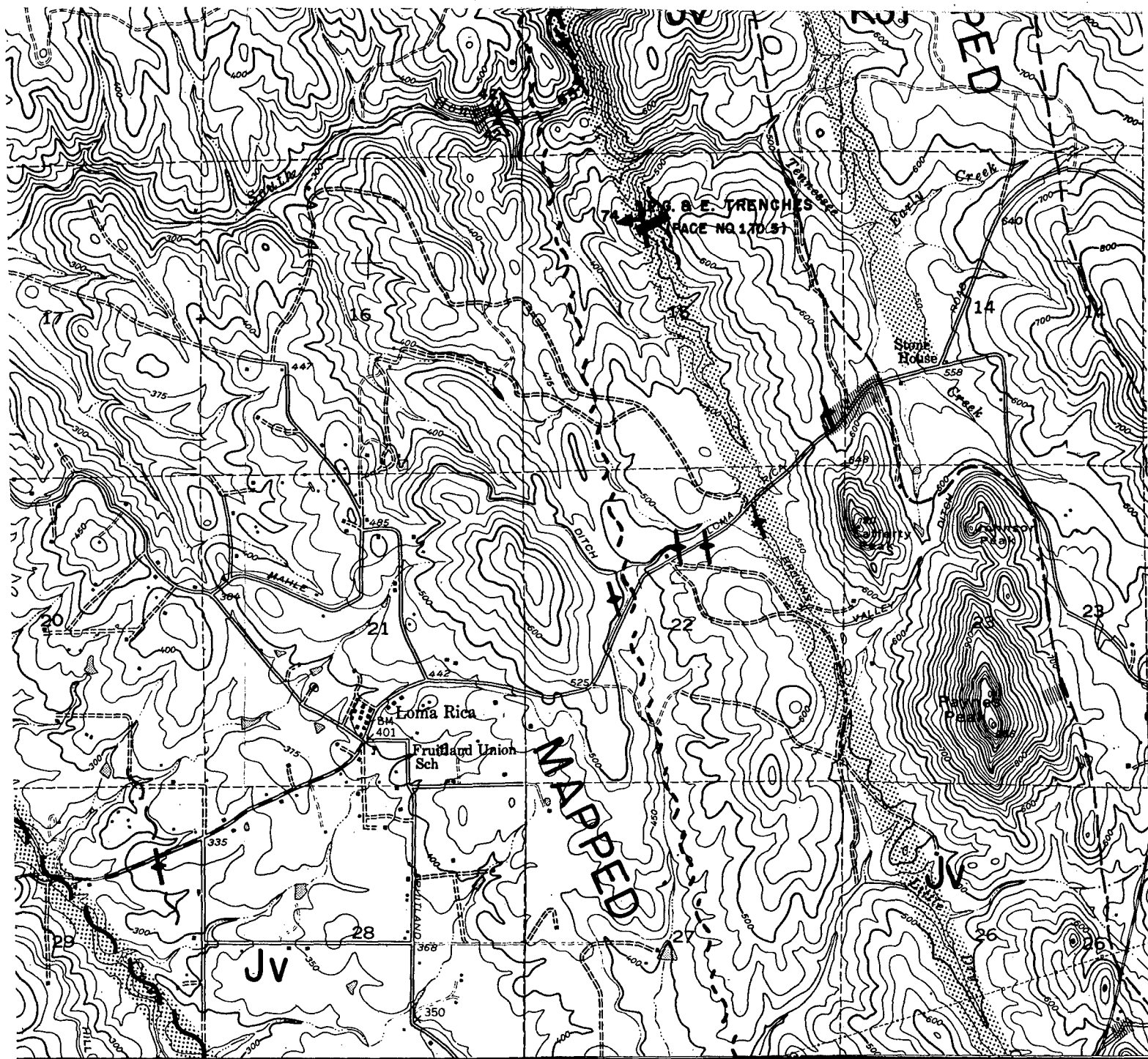
ROAD CLASSIFICATION

- | | |
|---------------------------------|---|
| Primary highway, hard surface | Light-duty road, hard or improved surface |
| Secondary highway, hard surface | Unimproved road |
| Interstate Route | U. S. Route |
| | State Route |



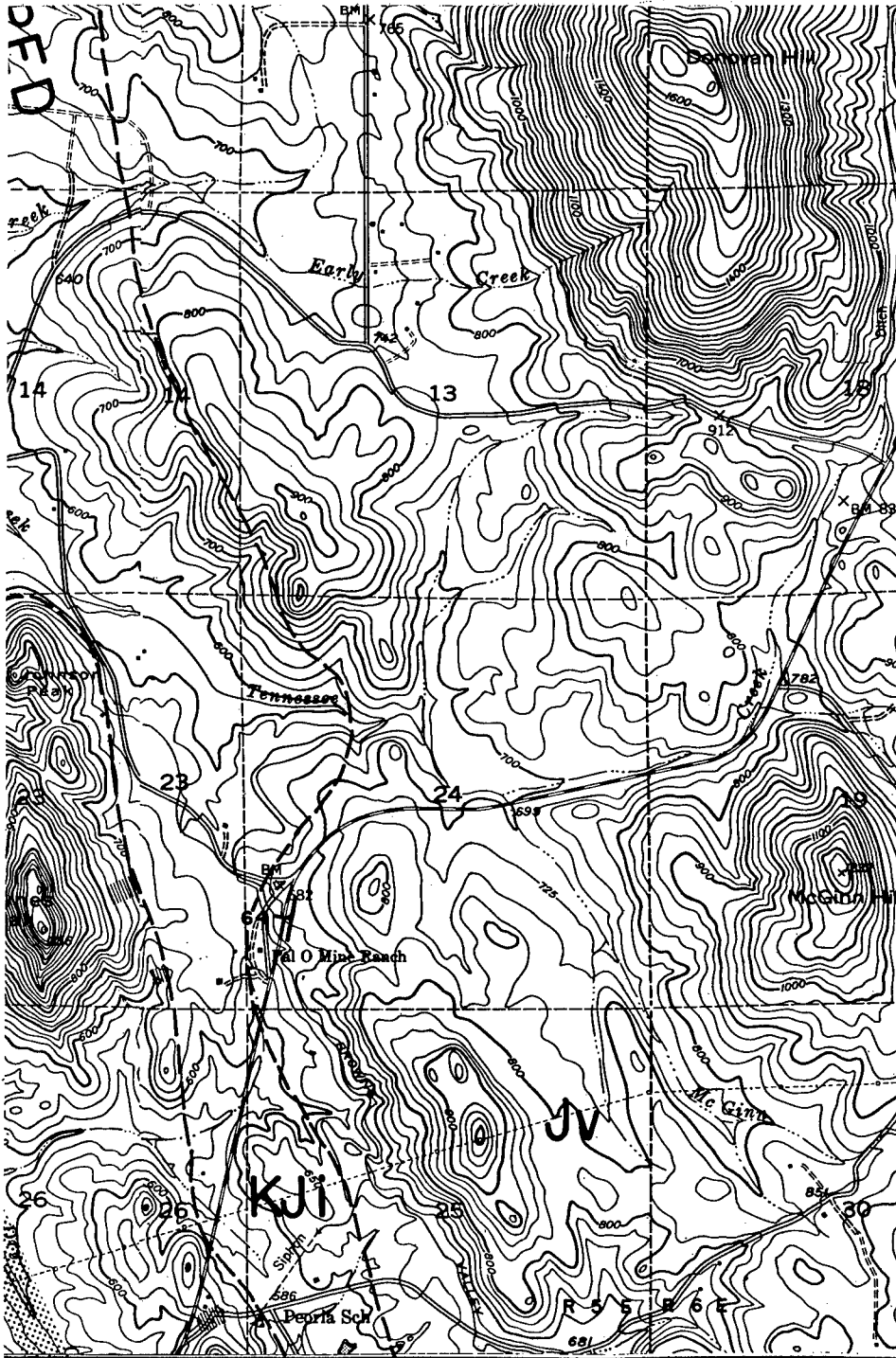
SCALE 1:24 000





SAFETY PAYS



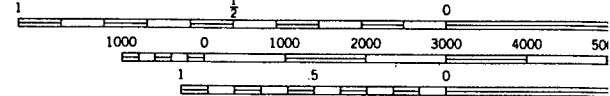


This map is a composite of the quadrangles Palermo, Bangor, Loma Rica, Honcut and Oregon California 7.5 minute series

ROAD CLASSIFICATION

Primary highway, hard surface _____ Light-duty road, hard or improved surface _____
 Secondary highway, hard surface _____ Unimproved road _____
 ○ Interstate Route ○ U. S. Route ○ State Route

SCALE 1:24 000



 REVISION DATE		DEPARTMENT C SACRAMENTO DISTRICT, SACRAMENTO,	
DESIGNED BY: _____		MA	
DRAWN BY: D. W. Paige		RE FAULT	
CHECKED BY: R. J. Anderson			
PREPARED BY: R. Treat, K. Buer J. Gewerth, A. Price, J. Musto			
SUBMITTED: P. J. Guthrie CHIEF, GEOLOGY SECTION			
APPROVAL RECOMMENDED: J. E. Anderson CHIEF, FONS. & MATLS BRANCH		APPROVED: [Signature] CHIEF	
PREPARED UNDER THE DIRECTION OF DONALD M O'SHEI COL., CORPS OF ENGINEERS, U. S. A. DISTRICT			

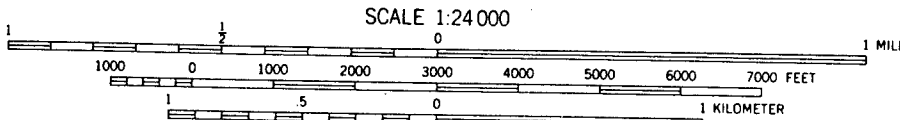
This map is a composite of U.S.G.S. quadrangles Palermo, Bangor, Rackerby, Loma Rica, Honcut and Oregon House, California 7.5 minute series.

ROAD CLASSIFICATION

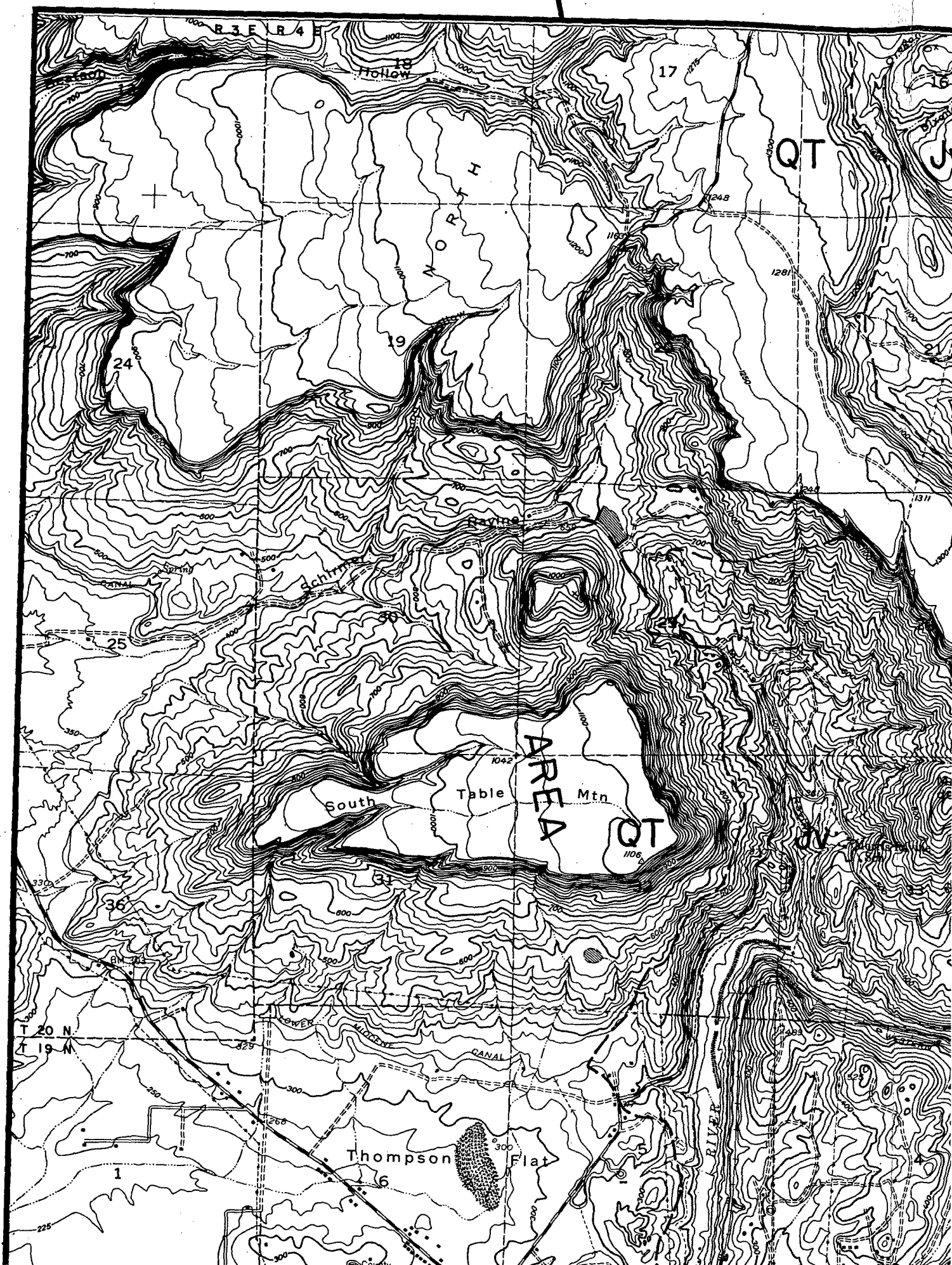
Primary highway, hard surface _____ Light-duty road, hard or improved surface _____

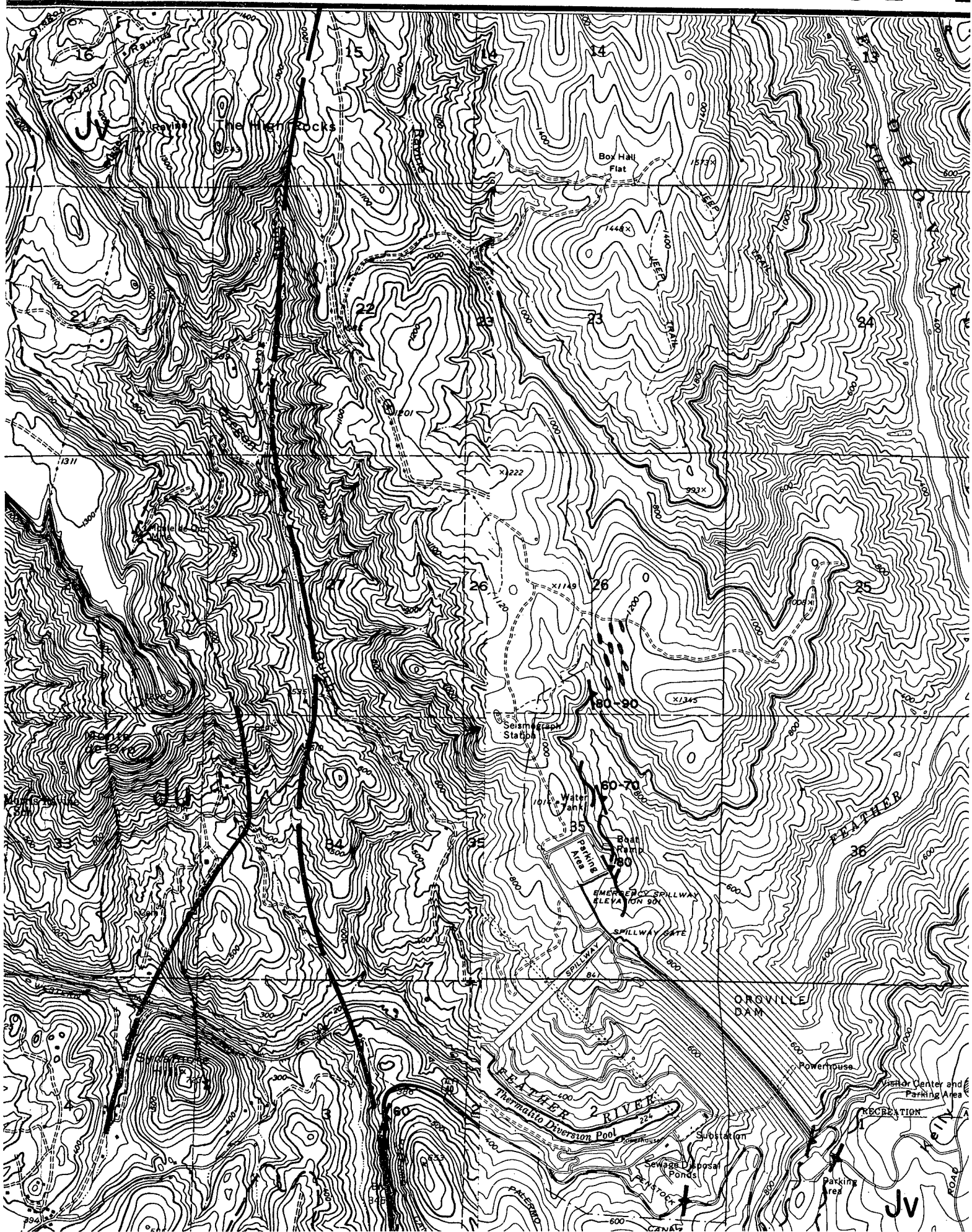
Secondary highway, hard surface _____ Unimproved road _____

○ Interstate Route ⬢ U. S. Route ○ State Route



REVISION	DATE	DESCRIPTION	BY	BY
DEPARTMENT OF THE ARMY SACRAMENTO DISTRICT, CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA				
DESIGNED BY:		MARYSVILLE LAKE PROJECT PARKS BAR ALTERNATE REGIONAL GEOLOGY FAULT EVALUATION STUDY		
DRAWN BY: <i>D. W. Paige</i>				
CHECKED BY: <i>R. J. Anderson</i>				
PREPARED BY: <i>R. Treat, K. Buer, J. Gewerth, A. Price, J. Musto</i>				
SUBMITTED: <i>P. A. Guthrie</i> CHIEF, GEOLOGY SECTION				
APPROVAL RECOMMENDED: <i>E. Scrandone</i> CHIEF, FONS. & MATLS. BRANCH		APPROVED: <i>[Signature]</i> CHIEF, ENGINEERING DIVISION		DATE:
PREPARED UNDER THE DIRECTION OF				
DONALD M. O'SHEI COL., CORPS OF ENGINEERS, U. S. A.		DISTRICT ENGINEER		
SCALE: AS SHOWN		SPEC. NO.		
FILE NO. YU-4-20-39				
SHEETS		SHEET NO.		
39/1 to 39/5		39/4		





[illegible]

EXPLANATI

TERTI

QT

Sedimentary and volcanic
western margin of map

JURASS

KJi

Mesozoic intrusive igneous
granite, granodiorite

UI

Ju

Metasedimentary rocks

Jv

Metavolcanic rocks,
pillowed and non-pillowed
crystal and lithic tuffs
diabasic to dacitic dikes
are described in the

Geologic contacts are
California, Chico She
the Geologic symbols
reconnaissance geolog
are designated "AREA"

The three main lineaments
terminated on this map
study.

--- Approximate geologic

Regional shear zone

Inferred shear zone

General location

Generalized tomb

Strike of dike

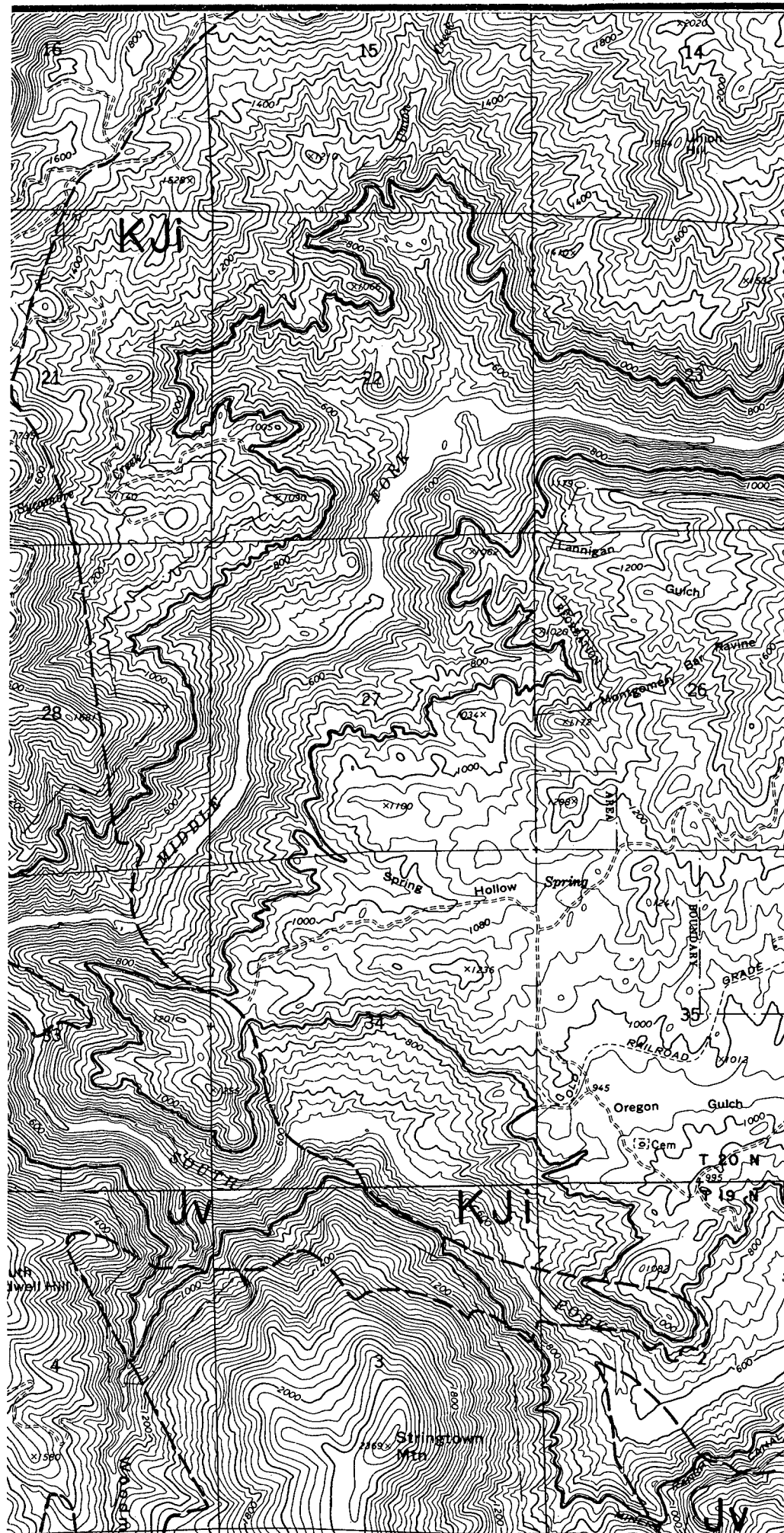
Strike and dip of

Strike and dip of

Strike and dip of

Strike and dip of

Location and orientation
with the 1 August
sequent aftershock



EXPLANATION OF SYMBOLS

TERTIARY TO QUATERNARY

- QT** Sedimentary and volcanic deposits. Undifferentiated along the western margin of map; locally overlies metavolcanic bedrock.

JURASSIC TO CRETACEOUS

- KJi** Mesozoic intrusive igneous rocks. Includes variations of granite, granodiorite, tonalite, gabbro, diorite, and quartz.

UPPER JURASSIC

- Ju** Metasedimentary rocks. Monte de Oro Formation north of Oroville.

- Jv** Metavolcanic rocks. Chiefly metamorphosed basaltic to andesitic, pillowed and non-pillowed flows and pyroclastics including crystal and lithic tuffs, tuff breccias or agglomerates with diabasic to dacitic dikes. Five groups of metavolcanic rocks are described in the project area (Plate III).

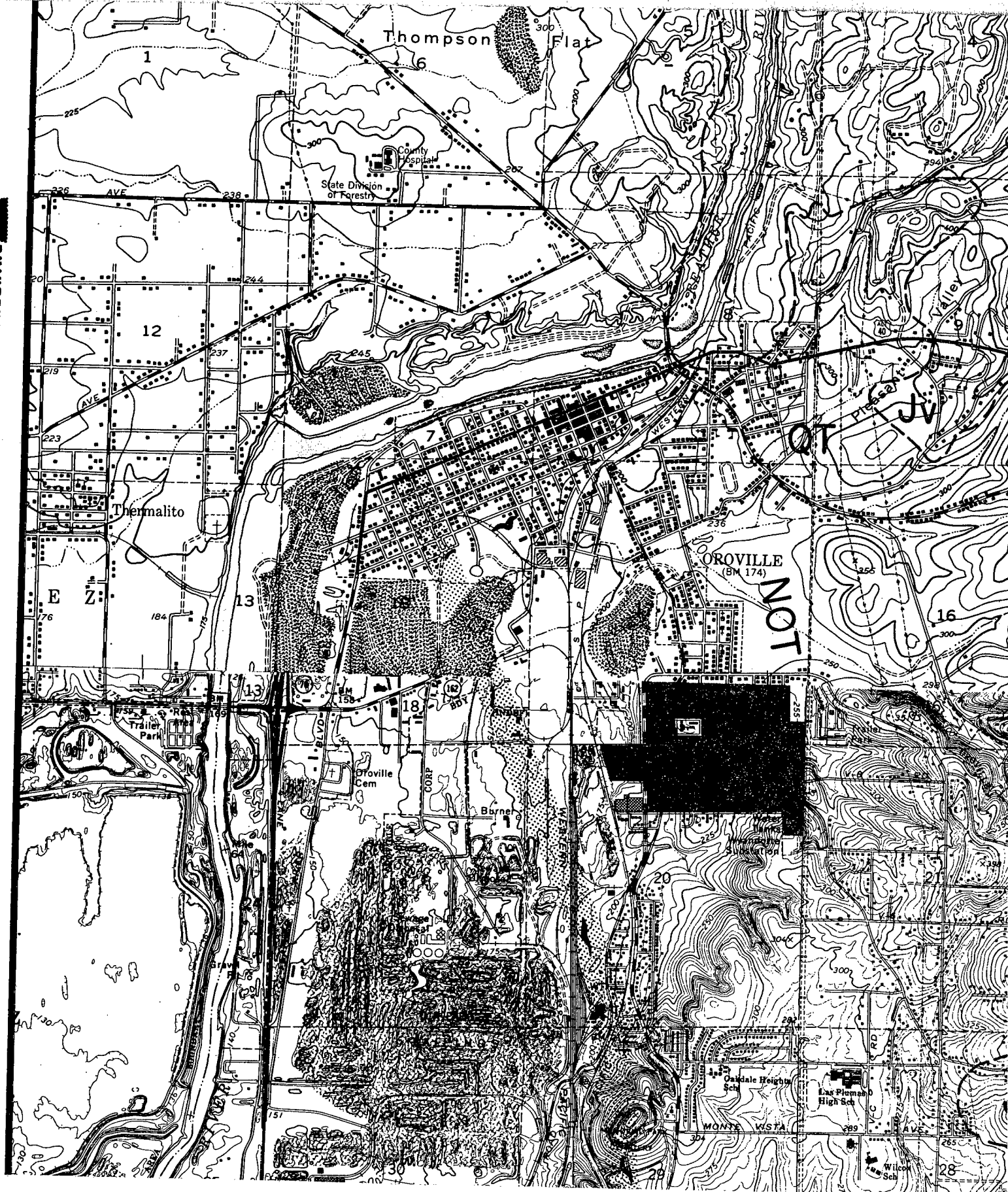
NOTES

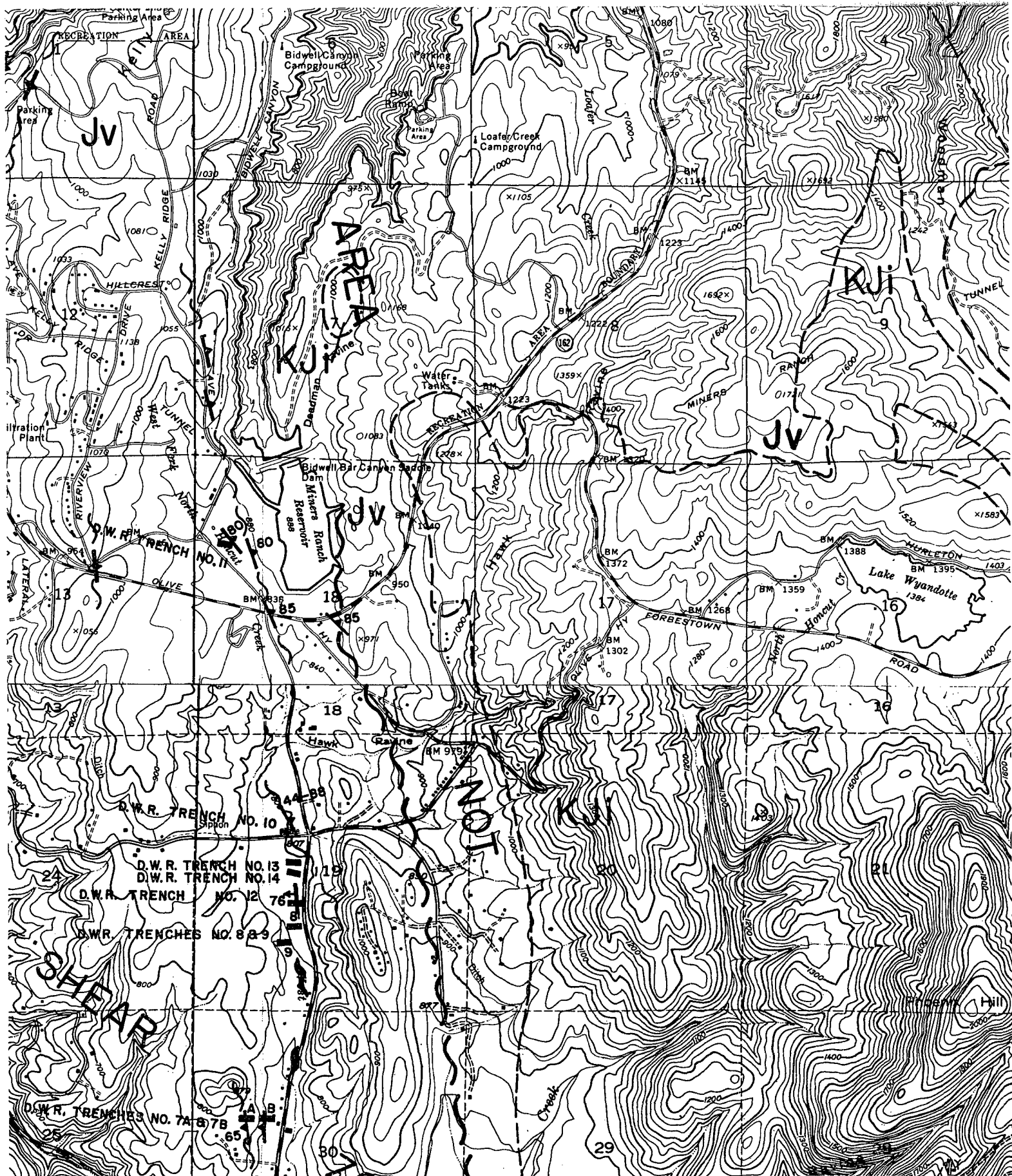
Geologic contacts are generalized from the Geologic Map of California, Chico Sheet (Burnett and Jennings 1962). Most of the Geologic symbols used are from Clark, 1976. Only reconnaissance geological mapping was done in some areas which are designated "AREA NOT MAPPED".

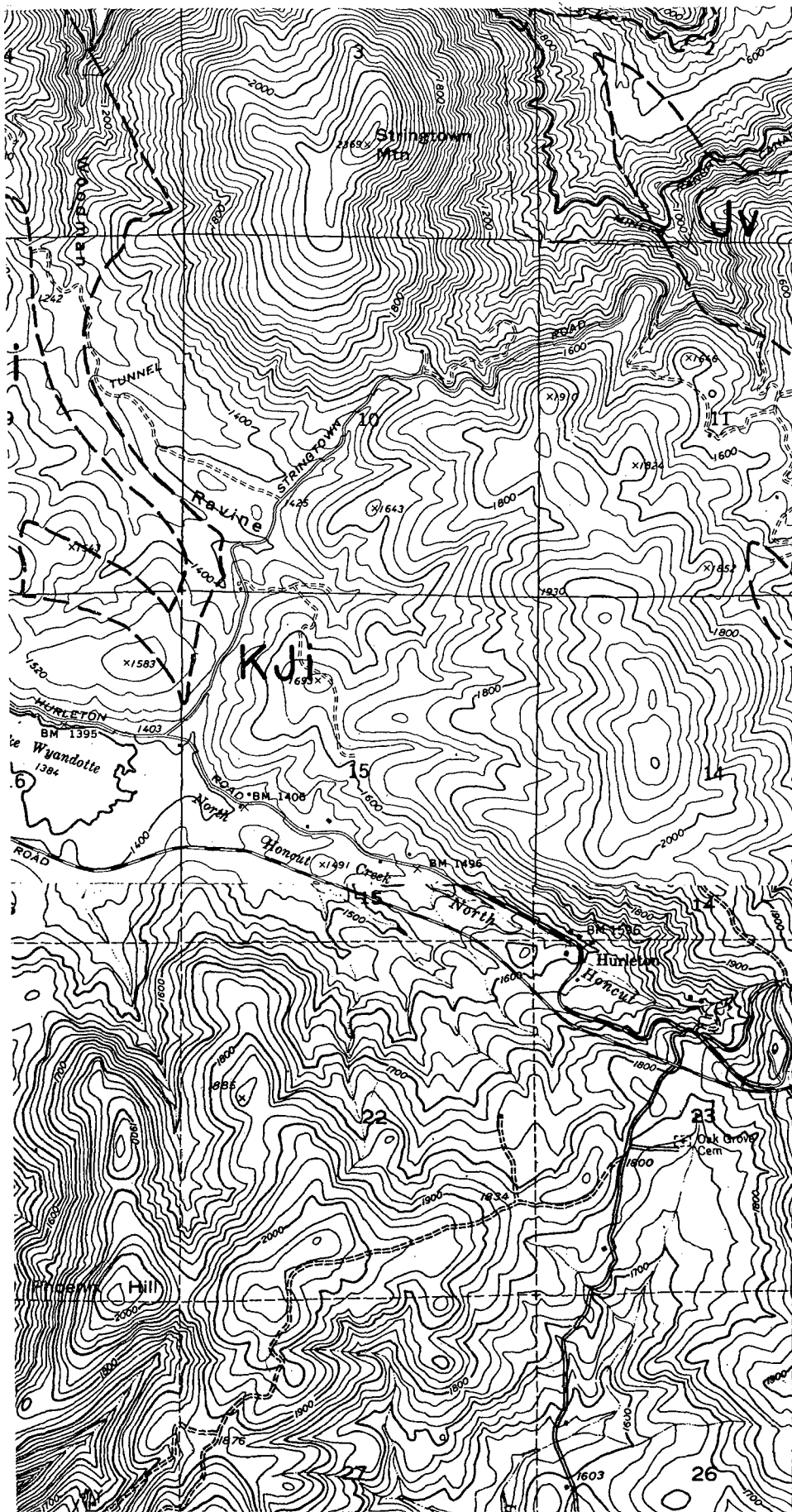
The three main lineaments extend northward from where they are terminated on this map but they were not investigated for this study.

- Approximate geologic contact
- ~~~~~ Regional shear zone boundary
- - - - - Inferred shear zone boundary
- ▨ General location of lineament
- Generalized tombstone outcrops
- ✕✕✕ Strike of dike
- 75 Strike and dip of foliation; vertical foliation
- 65 Strike and dip of foliation within a shear
- 55 Strike and dip of bedding
- 70 Strike and dip of fault
- Location and orientation of ground cracks associated with the 1 August 1975 Oroville earthquake and subsequent aftershocks (Sherburne and Hauge, 1975).









70°
Location and orienta
with the 1 August 19
sequent aftershocks



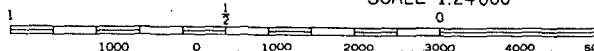
NOTE:

This map is a composite of L
quadrangles Oroville, Oroville
Palermo and Bangor Califor
minute series.

ROAD CLASSIFICATION

Primary highway, hard surface	Light-duty road, hard or improved surface
Secondary highway, hard surface	Unimproved road
Interstate Route	U. S. Route
	State Route

SCALE 1:24 000

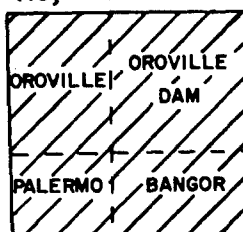


70°



Location and orientation of ground cracks associated with the 1 August 1975 Oroville earthquake and subsequent aftershocks (Sherburne and Hauge, 1975).

Key to sheets



NOTE:

This map is a composite of U.S.G.S. quadrangles Oroville, Oroville Dam, Palermo and Bangor California 7.5 minute series.

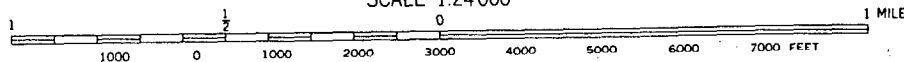
ROAD CLASSIFICATION

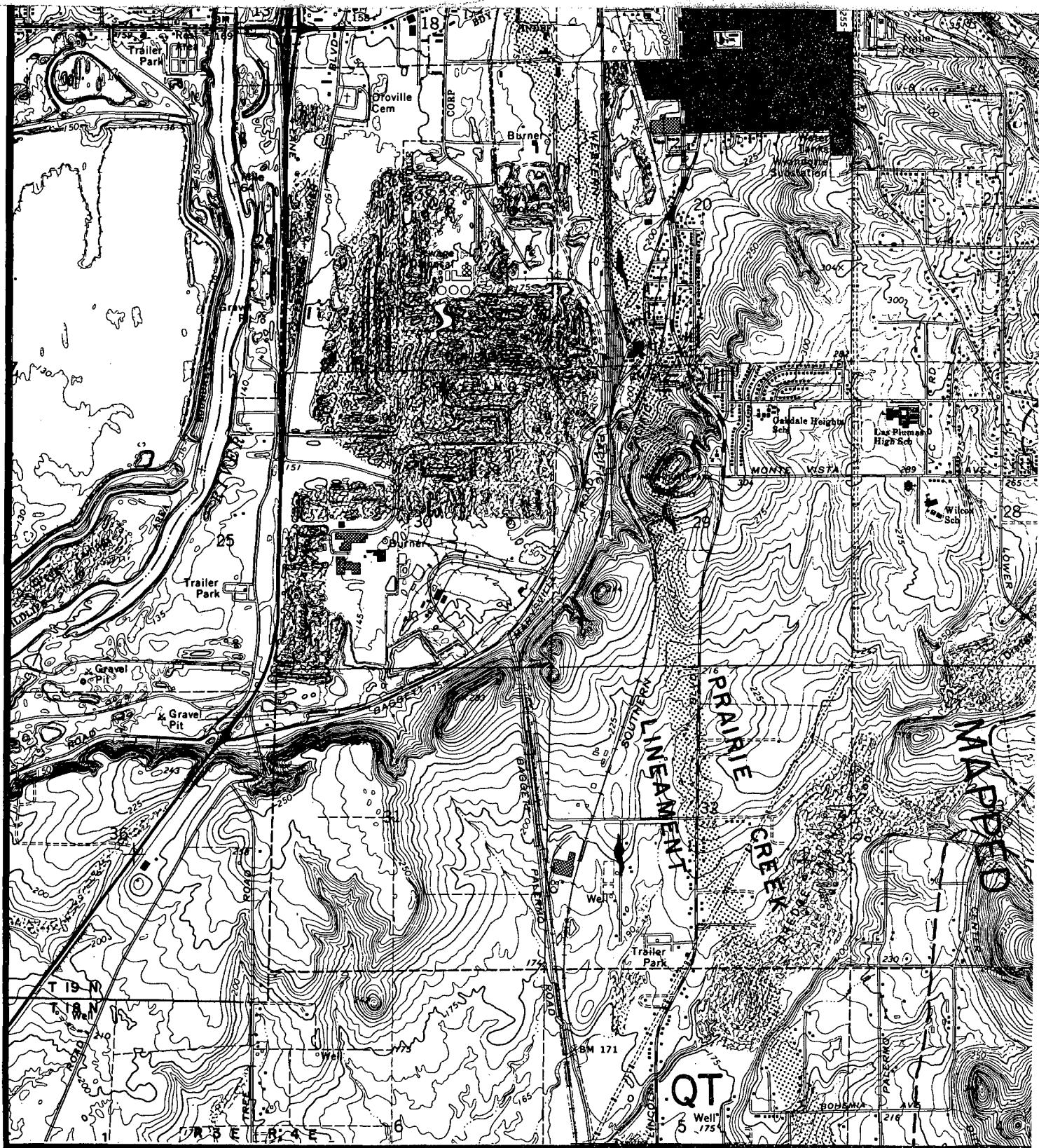
Primary highway, hard surface ——— Light-duty road, hard or improved surface ———
 Secondary highway, hard surface ——— Unimproved road ———
 Interstate Route U. S. Route State Route

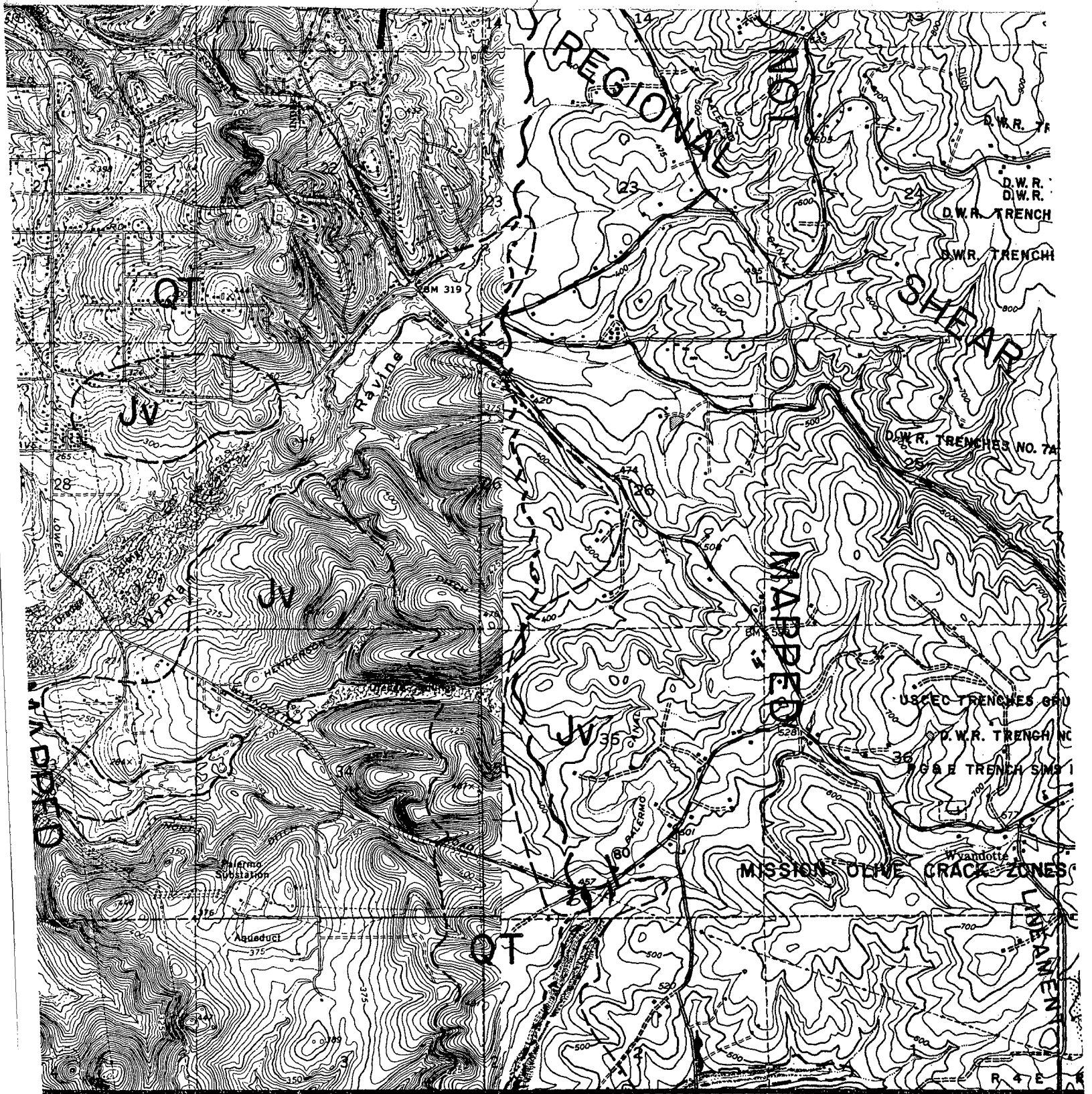


QUADRANGLE LOCATION

SCALE 1:24 000



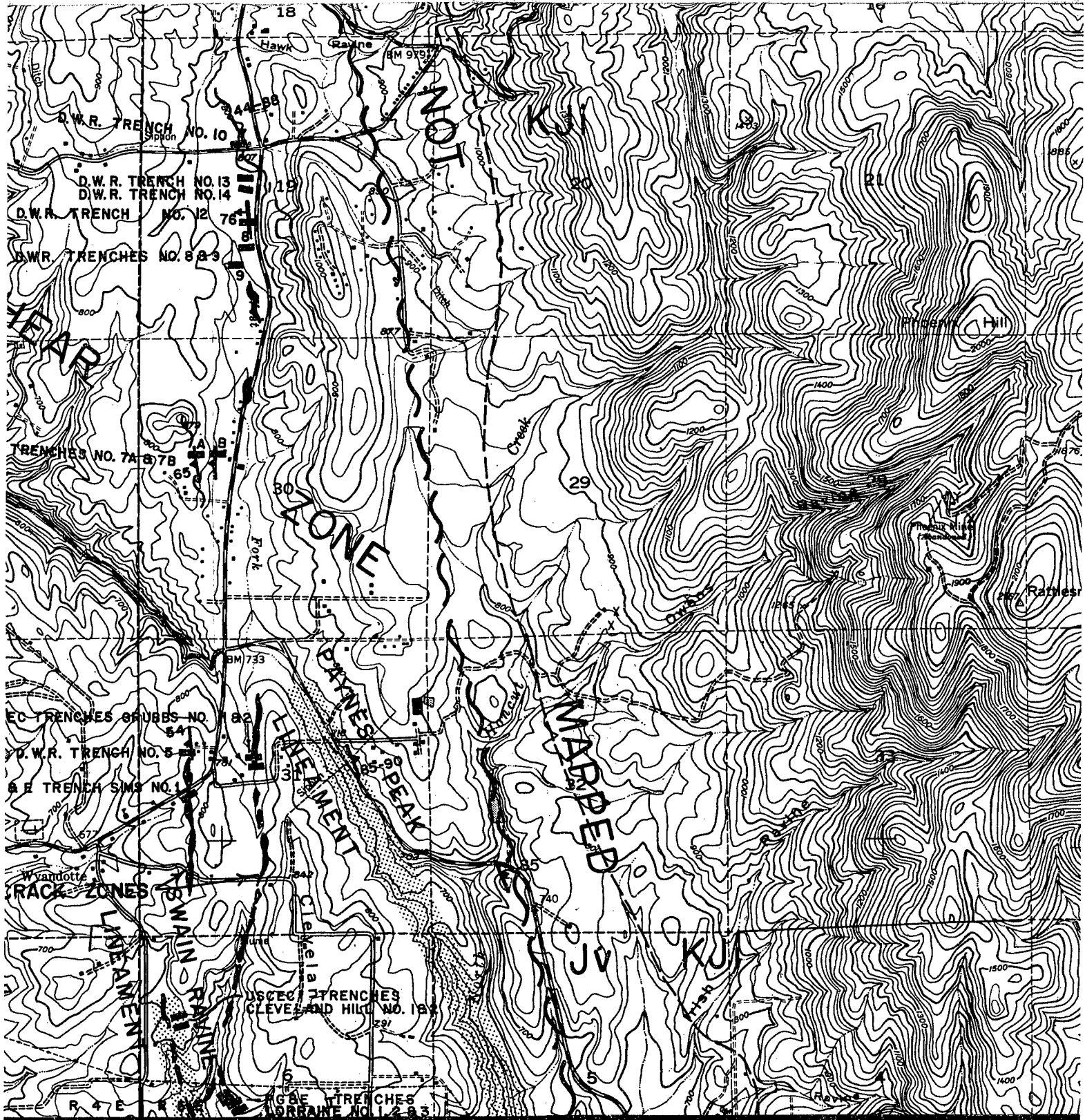




12



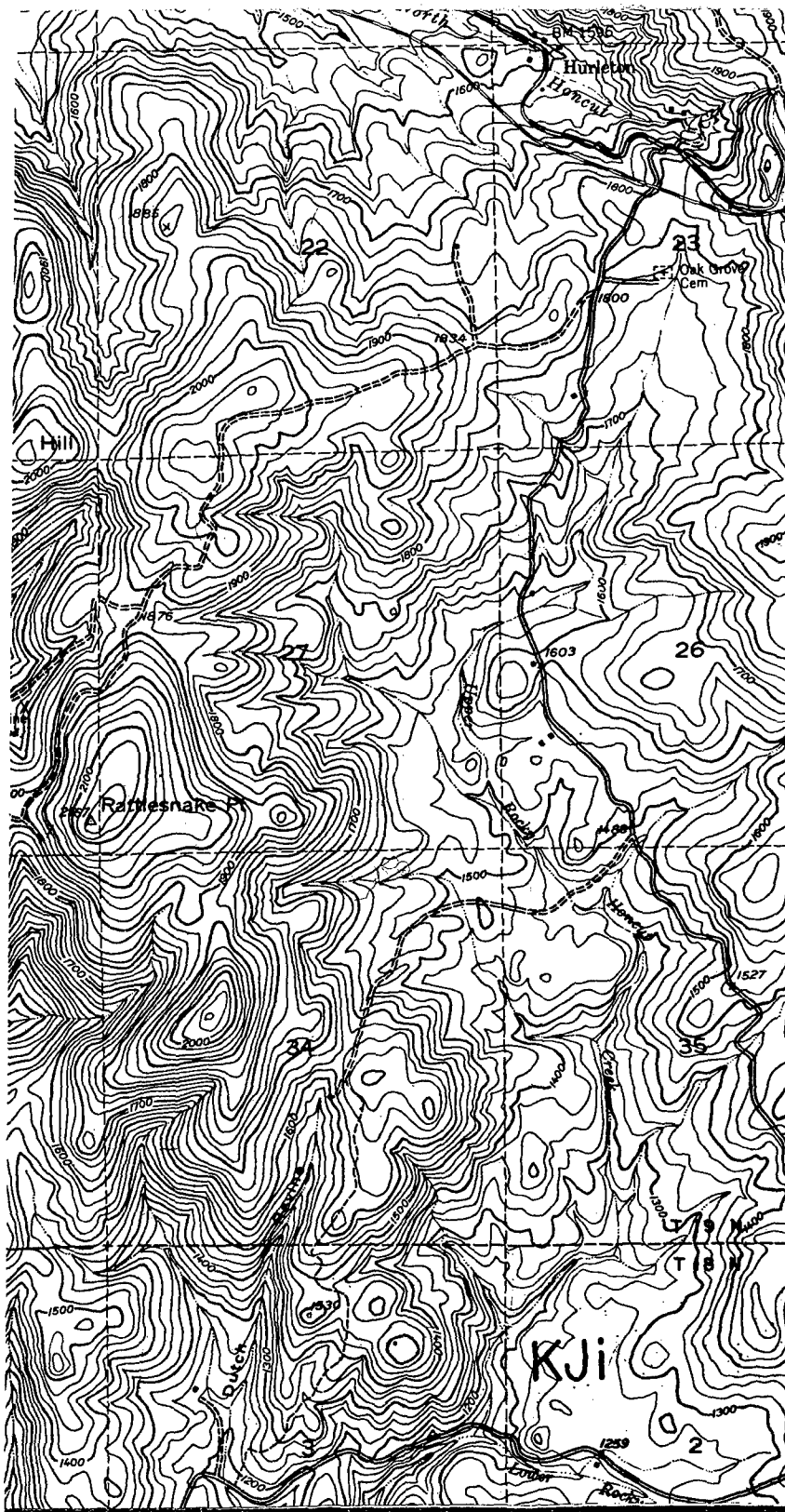
SAI



SAFETY PAYS



13



NOTE:

This map is a composite of U.S.G.S. quadrangles Oroville, Oroville Dam, Palermo and Bangor California 7.5 minute series.

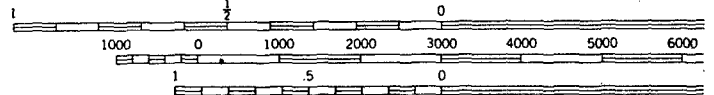
ROAD CLASSIFICATION

Primary highway, hard surface _____ Light-duty road, hard or improved surface _____
 Secondary highway, hard surface _____ Unimproved road _____

○ Interstate Route ○ U. S. Route ○ State Route

QUAD

SCALE 1:24 000



REVISION	DATE	DESCRPT
<p align="center">DEPARTMENT OF THE SACRAMENTO DISTRICT, CORPS SACRAMENTO, CALIFORNI</p>		
DESIGNED BY: _____ DRAWN BY: <i>D. W. Paige</i> CHECKED BY: <i>R. J. Anderson</i> PREPARED BY: <i>R. Treat, K. Buer, J. Gewerth, A. Price, J. Musto</i> SUBMITTED: <i>P. J. Guthrie</i> CHIEF, GEOLOGY SECTION		<p align="center">MARYSVIL PARKS REGION FAULT EV</p>
APPROVAL RECOMMENDED: <i>J. Sciandrone</i> CHIEF, FDNS & MAT. BRANCH PREPARED UNDER THE DIRECTION OF DONALD M. O'SHEI COL., CORPS OF ENGINEERS, U. S. A.		APPROVED: <i>J. P. [Signature]</i> CHIEF, ENGINEERING DISTRICT ENGINEER

TE:

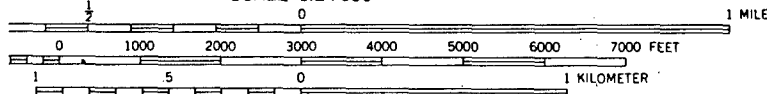
This map is a composite of U.S.G.S. quadrangles Oroville, Oroville Dam, Palermo and Bangor California 7.5 minute series.

ROAD CLASSIFICATION

Light-duty road, hard or improved surface
Unimproved road
U. S. Route State Route



SCALE 1:24 000



DATE	DESCRIPTION	BY	BY
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DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

MARYSVILLE LAKE PROJECT
PARKS BAR ALTERNATE
REGIONAL GEOLOGY
FAULT EVALUATION STUDY

son
Treat, K. Buer
Price, J. Musio

thie
GEOLOGY SECTION

RECOMMENDED:
andrews
S. & MATL SPRANCH

APPROVED: *[Signature]*
CHIEF, ENGINEERING DIVISION

DATE:

UNDER THE DIRECTION OF

LD M. O'SHEI

ENGINEERS, U. S. A.

DISTRICT ENGINEER

SCALE: AS SHOWN

SPEC. NO.

FILE NO. YU-4-20-39

SHEETS

SHEET NO.

39/1 to 39/5

39/5

PLATE V

15